THE SNELLIUS-EXPEDITION

IN THE EASTERN PART OF THE NETHERLANDS EAST-INDIES 1929-1930

UNDER LEADERSHIP OF
P. M. VAN RIEL
DIRECTOR OF THE AMSTERDAM BRANCH OFFICE OF THE
NETHERLANDS METEOROLOGICAL INSTITUTE

VOLUME II

OCEANOGRAPHIC RESULTS

PART V

THE BOTTOM WATER

CHAPTER I

INTRODUCTORY REMARKS AND OXYGEN CONTENT

BY

P. M. VAN RIEL

1943

TO BE OBTAINED OF THE PRINTERS AND PUBLISHERS
E. J. BRILL - LEIDEN

SNELLIUS-EXPEDITIE

WETENSCHAPPELIJKE UITKOMSTEN DER SNELLIUS-EXPEDITIE

ONDER LEIDING VAN

P. M. VAN RIEL

DIRECTEUR VAN DE FILIAALINRICHTING VAN HET NEDERLANDSCH METEOROLOGISCH INSTITUUT TE AMSTERDAM

VERZAMELD IN HET OOSTELIJKE GEDEELTE VAN NEDERLANDSCH OOST-INDIË AAN BOORD VAN H. M. WILLEBRORD SNELLIUS

ONDER COMMANDO VAN

F. PINKE

LUITENANT TER ZEE DER 1e KLASSE

1929–1930

UITGEGEVEN DOOR DE MAATSCHAPPIJ TER BEVORDERING VAN HET NATUURKUNDIG ONDERZOEK DER NEDERLANDSCHE KOLONIËN EN HET NEDERLANDSCH AARDRIJKSKUNDIG GENOOTSCHAP

GEDRUKT DOOR EN TE VERKRIJGEN BIJ

E. J. BRILL — LEIDEN

THE SNELLIUS-EXPEDITION

IN THE EASTERN PART OF THE NETHERLANDS EAST-INDIES 1929-1930

UNDER LEADERSHIP OF

P. M. VAN RIEL

DIRECTOR OF THE AMSTERDAM BRANCH OFFICE OF THE NETHERLANDS METEOROLOGICAL INSTITUTE

VOLUME II

OCEANOGRAPHIC RESULTS

PART V

THE BOTTOM WATER

CHAPTER I

INTRODUCTORY REMARKS AND OXYGEN CONTENT

BY

P. M. VAN RIEL

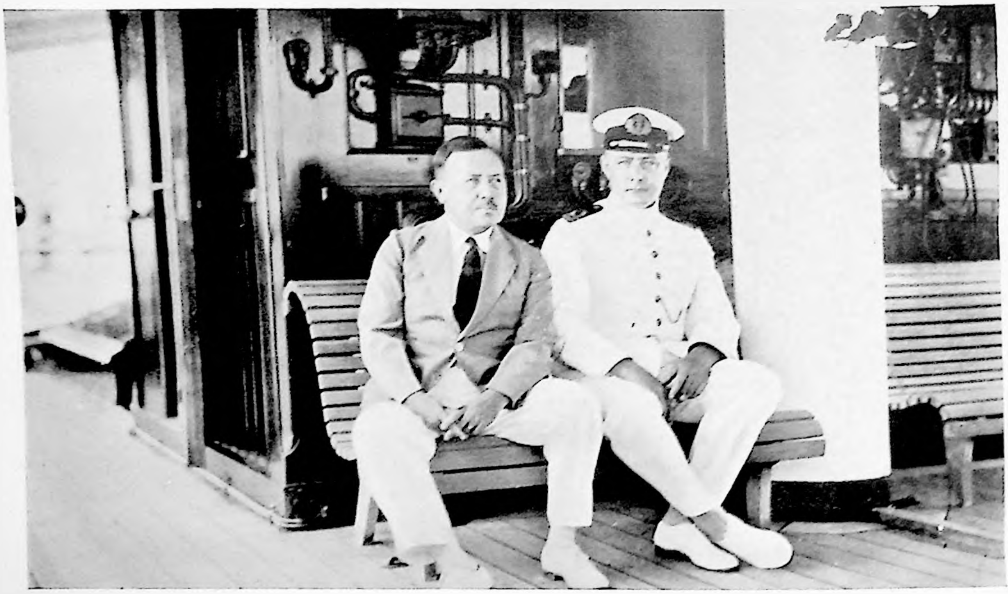
1943

TO BE OBTAINED OF THE PRINTERS AND PUBLISHERS

E. J. BRILL - LEIDEN

CONTENTS

I. Introduction 1
II. Observations from previous researches 2
A. Temperature 4
B. Salinity 8
C. Oxygen. 9
III. Depths of observation 11
A. Thermometer depths 11
B. Wire depths 11
C. Echo depths 13
IV. Oxygen observations 25
A. Seasonal variations and the accuracy of the observations 25
B. Multiple bottom water observations 36
C. Distribution of Oxygen in the bottom water 43
a. Influence of Pacific water 44
b. Influence of Indian Ocean water 61
c. Influence of Southern China Sea water 66
d. Comparison of the oxygen content near the bottom with the mean content determined at corresponding depths in the open sea 68



The commander and the leader of the expedition on the bridge of H. M. S. Willebrord Snellius

I. INTRODUCTION

This part of the „Snellius" Reports may be regarded as a continuation of Vol. II Part 2 Ch. II in which we dealt with the bottom configuration and also considered the potential temperature of the abyssal layers at several stations in the various inland seas, and the relation between the properties of the bottom and deep water inside and those of the layers outside the troughs and basins at a level corresponding to their deepest entrance. This relation, further, helped us to estimate the depth of the deepest passage in a dividing ridge where soundings are scarce or totally lacking. The results are shown on Plate IV of Vol. II Part 2 Ch. II where the arrows give the direction of the flow of bottom water and indicate the part which the Pacific and Indian Oceans and the China sea play in the renewal of the bottom water in the isolated basins.

In the following we shall deal with the properties of the bottom water at *all stations* and examine their distribution in each basin separately. As Dr. Hardon, the chemist of the expedition, who is charged with working out the oxygen material, kindly allowed me to make use of the bottom oxygen observations, we shall not confine ourselves to temperature and salinity only but include the bottom oxygen content. It will appear that the knowledge of the oxygen distribution is of importance also to the physical oceanographer and lends a welcome aid in determining the movements of the abyssal layers and their origin. As the oxygen distribution may be of interest for biological and geological purposes we will treat this item first. The temperature and salinity distribution in the bottom water will be dealt with in the continuation of this part.

I should like to express my indebtedness to the physicist of the expedition Dr. H. C. Hamaker for his assistance in the critical examination of the observation material. Further I offer my hearty thanks to Mr. L. van Eyck for his help in many instances and for drawing fair copies of charts and diagrams and to Mrs. D. Kuenen-Wicksteed who kindly aided me with the translation of this report.

v. R.

II. OBSERVATIONS FROM PREVIOUS RESEARCHES [1])

The bottom observations from previous expeditions are limited to those from the „Challenger" 1874—1875, the „Gazelle" 1875, the „Siboga" 1899—1900 and the „Planet" 1906. On Plate II of Vol. I Ch. I of the „Snellius" Reports the stations where these observations were made are marked.

The bottom temperature and salinity observations within the limits of Plate I are contained in Table 1; the oxygen observations will be dealt with separately. The observations of the „Siboga" concern only temperature. These observations, however, have never been published, as the corrections for the thermometers were lost owing to the death of the expert to whom their elaboration had been entrusted. This is all the more to be regretted because several of the observations were made with reversing thermometers.

TABLE 1. Bottom temperature and salinity observations from previous researches within the limits of Pl. I.

Station nr.	Year, Date	Position		Depth m	Temp. in situ °C.	Pot. Temp. °C.	Salinity ‰
		Lat.	Long.				
Sulu sea.							
			CHALLENGER				
	1874	N.	E.				
202	27—X	8°32′	121°55′	4663	10.25	9.56	34.56
	1875						
211	28—I	8°00′	121°42′	4069	10.33	9.74	34.37
Celebes sea.							
			CHALLENGER				
	1874	N.	E.				
198	20—X	2°55′	124°53′	3931	3,83	3.43	34.89
199	22—X	5°44′	123°34′	4755	3.72	3.22	34.25
	1875						
213	8—II	5°47′	124°01′	3749	3.61	3.24	34.65
Pacific Ocean.							
			CHALLENGER				
	1875	N.	E.				
214	10—II	4°33′	127°06′	914	5.47	5.39	34.58
							34.70
215	12—II	4°19′	130°15′	4663	1.89	1.47	34.46
							34.57
216	16—II	2°46′	133°58′	3063	1.89	1.65	34.92
216*a*	16—II	2°56′	134°11′	3658	1.92	1.61	34.66

[1]) See also the data published by W. E. Ringer (20) and referring to a more extensive area.

Station nr.	Year, Date	Position		Depth m	Temp. in situ °C.	Pot. Temp. °C.	Salinity ‰
		Lat.	Long.				
			GAZELLE				
	1875	S.	E.				
105	26—VI	0°05′	132°29′	4389	1.7	1.32	35.4
		N.	E.				
106	28—VI	0°30′	134°19′	4535	1.9 [1]	1.49	35.2
			PLANET				
	1906	S.	E.				
187	7—IX	0°11′	132°08′	3385	1.4	1.14	(34.63)
188	7—IX	0°13′	132°14′	2920	1.4	1.19	34.72
189	7—IX	0°15′	132°23′	2440	—	—	34.67
189*a*	7—IX	0°17′	132°24′	475	10.2	10.14	34.69
190	8—IX	0°05′	133°38′	3395	1.4	1.14	34.69
	1907	N.	E.				
220	22—I	7°31′	134°33′	415	—	—	34.49
221	22—I	7°30′	134°26′	1388	—	—	34.58
222	23—I	7°36′	133°23′	4733	—	—	34.70
223	23—I	7°36′	132°46′	4066	1.7	1.35	—
224	24—I	7°36′	132°04′	4496	1.7	1.30	34.69
226	25—I	7°39′	130°12′	5621	1.3	0.77	—
227	26—I	7°36′	129°32′	5556	—	—	34.65
229	27—I	7°18′	127°48′	6113	1.6	0.99	—
234	28—I	6°55′	126°44′	5330	1.6	1.10	—
236 [2]	28—I	6°56′	126°30′	1113	7.6?	7.48?	34.58
Molukken sea.							
			CHALLENGER				
	1874	S.	E.				
196	13—X	0°48′.5	126°58′.5	1509	2.7	2.59	34.88
		N.	E.				
197	14—X	0°41′	126°37′	2195	2.17	2.01	34.98
Ceram sea.							
			GAZELLE				
	1875	S.	E.				
102	12—VI	2°54′.5	127°46′.5	3145	3.3	3.02	35.5
103	13—VI	2°37′.5	129°19′.5	832	4.2	4.14	—
104	14—VI	2°42′.5	130°46′	1820	3.7	3.55	35.0
			PLANET				
	1906	S.	E.				
186	5—IX	1°53′	128°56′	958	4.9	4.82	34.61
Banda sea.							
			CHALLENGER				
	1874	S.	E.				
193	28—IX	5°24′	130°37′	5121	3.31	2.77	34.66
195	3—X	4°21′	129°07′	2606	3.3	3.08	34.66

[1]) According to p. 41 of Forschungsreise S.M.S. „Gazelle". Physik und Chemie, 1888. On p. 58 is to be found 1°.8 C.

[2]) Temperature abnormally high.

Station nr.	Year, Date	Position Lat.	Position Long.	Depth m	Temp. in situ °C.	Pot. Temp. °C.	Salinity ‰
			GAZELLE				
	1875	S.	E.				
99	30—V	7°35′	125°27′	4243	2.9	2.50	34.6
100	31—V	6°33′.4	126°29′.5	4243	3.0	2.60	34.5
Aroe basin.							
			CHALENGER				
	1874	S.	E.				
191	23—IX	5°41′	134°04′.5	1463	4.14	4.02	—
191*a*	24—IX	5°26′	133°19′	1061	5.06	4.97	34.81
Sawoe sea.							
			GAZELLE				
	1875	S.	E.				
96	12—V	9°56′.5	121°52′	2981	3.2	2.94	—
97	13—V	9°58′.5	122°54′.7	3164	3.3	3.02	34.7
98	27—V	8°48′	124°15′	3758	3.3	2.94	—
Indian Ocean.							
			GAZELLE				
	1875	S.	E.				
94	8—V	12°27′.7	119°03′.5	5221	1.1	0.63	—
95	10—V	11°18′.3	120°08′.5	4078	1.1	0.77	—

A. **Temperature.** The „Gazelle" and „Planet" (1, 2) observations were determined in tenths of a degree Celsius; those of the „Challenger" in tenths of a degree Fahrenheit (3) were converted in Celsius degrees to 100ths. The potential temperatures were determined from the tables and diagrams by Bj. Helland-Hansen (4) for depths of 1000 m and more. For lesser depths G. Schott's diagram (5) was used.

The observations of the three expeditions mentioned above, in so far as they lay *within the area of research* of the „Snellius", are included in Table 2, for comparison with the „Snellius" results. Differences with the „Challenger" and „Gazelle" observations below the level of the minimum temperature, may be expected, as only part of the adiabatic increase of temperature *in situ* below this level could be observed with the maximum and minimum thermometers.

Consequently the depth of the minimum level and the temperature prevailing there are given in the first column of Table 2. They are deduced from the T.D. curves and may differ slightly, therefore, from those in Table 4, Vol. II Part 2 Ch. II which represent the temperatures actually observed (cf p. 55 of the above mentioned chapter). The potential temperatures were only calculated for the observations below the minimum level.

In the *Sulu sea* the observations lie below the minimum level. At Ch. St. 202, therefore, there cannot be a lower temperature than at Ch. St. 211. Both values, compared to the „Snellius" observations, are too low.

In the *Celebes sea*, also, the observation depths are below the minimum level. Ch. Sts. 199 and 213 were compared with Sn. St. 57; the agreement of the potential temperatures is good, if we take into consideration that readings of the thermometer on the „Challenger" are expressed in tenths of a degree Fahrenheit. The temperature of Ch. St. 198 is too high.

In the *Pacific Ocean* Ch. St. 214 only lies above the minimum level. This station, close to the bank of the Nenoesa islands, has a temperature of 5°.47 at 914 m, a value in accordance with that

found in the neighbourhood. At the two ,,Planet" stations 229 and 234 a temperature was observed differing very little from the minimum temperature, although the depth is far below the minimum level, so that these temperatures must be considered too low. Ch. St. 215 again gives too high a temperature.

In the *Molukken sea* the ,,Challenger" temperatures differ little from those of the ,,Snellius".

In the *Ceram sea* G. St. 102 apparently lies in a confined depression of the bottom which would account for the high temperature. According to the observations in the Boeroe basin (Sn. St. 330) a potential bottom temperature of 3°.02 in this depression would indicate a deepest threshold at 2000 m depth, while the depth chart of Vol. II Part 2 Ch. II, southern sheet, gives a deepest connection of the surroundings with the position of G. St. 102 at a depth of about 2500 m. The temperature in situ of 3°.3 seems to us, therefore, too high. To judge the accuracy of the two other ,,Gazelle" observations a comparison does not yield much certainty on account of the small depth and the action of periodic and non-periodic variations at 800 m. The bottom observation of Pl. St. 186 agrees well with the serial observations of Sn. St. 84.

In the *Banda sea* the observations lie below the depth of the minimum level, with the exception of Ch. St. 195. A bottom temperature of 3°.30 just above this level seems too high for this station. On the other hand Ch. St. 193 yields a result which agrees well with ours. G. St. 99 and G. St. 100 were compared with Sn. St. 246. They gave disagreeing temperatures for the same depth, which lies about 1400 m below the minimum level. Both temperatures are lower than the minimum and must therefore be considered as too low.

In the *Aroe basin* Ch. St. 191 was compared with Sn. Sts. 99 and 104; Ch. St. 191*a* with Sn. Sts 100 and 101. The ,,Challenger" temperatures seem to be a little too high, although this is not certain, for the reasons given above (,,Ceram sea"). All observations are made above the minimum level.

In the *Sawoe sea* the case is reversed. Consequently with the maximum and minimum thermometers the observed temperatures will have been too low. This proves to be the case at G. Sts. 96—98, and the temperatures are even lower than those at the minimum level at 2250 m below the surface.

In the *Indian Ocean* the same temperature in situ of 1°.1 C. was registered at G. Sts. 94 and 95. Probably in both cases the minimum temperature was observed so that these determinations are too low in view of the observation depths. The difference with G. St. 95, however, is very slight.

According to Table 2 there seems to be a good agreement with the ,,Snellius" temperatures at a number of stations. With regard to ,,Challenger" observations, carried out with maximum and minimum thermometers this agreement will often be due to accident. To test this we must distinguish between observations below and above the minimum level.

TABLE 2. Comparison of the bottom temperature and salinity observations from previous researches with those obtained by the Snellius-expedition.

Area	Year, Date	Station nr.	Position		Depth m	Temp. in situ °C	Pot. temp. °C	Salinity ‰
			Lat.	Long.				
			N.	E.				
Sulu sea.	27-X -'74	Ch. 202	8°32′	121°55′	4663	10.25	9.56	34.56
Min. temp. in situ $10^{\circ}.07^{5}$	6-IX -'29	Sn. 64	7°41′	$121^{\circ}01^{5}{}'$	4070	10.44^{5}	9.84^{5}	34.48
at a depth of 1200 m. St. 64.	28-I -'74	Ch. 211	8°00′	121°42′	4069	10.33	9.73	34.37
Celebes sea.	22-X -'74	Ch. 199	5°44′	123°34′	4755	3.72	3.22	34.25
Min. temp. in situ $3^{\circ}.57^{5}$ at	4-IX -'29	Sn. 57	$5^{\circ}49^{5}{}'$	123°13′	4490	3.75	3.28^{5}	34.60
a depth of 2500 m. Mean	8-II -'75	Ch. 213	5°47′	124°01′	3749	3.61	3.24	34.60
value of sts. 53, 54 and 57.	4-IX -'29	Sn. 57	$5^{\circ}49^{5}{}'$	123°13′	3750	3.68	3.31	34.60
	20-X -'74	Ch. 198	2°55′	124°53′	3931	3.83	3.43	34.89
	24-VIII-'29	Sn. 53	$2^{\circ}11^{5}{}'$	124°02′	3930	3.69	3.30	34.58
	24-VIII-'29	Sn. 54	$1^{\circ}46^{5}{}'$	124°34′	3886	3.67^{5}	3.29^{5}	34.54

Area	Year, Date	Station nr.	Position		Depth m	Temp. in situ °C	Pot. temp °C	Salinity ‰
			Lat.	Long.				
Pacific Ocean.	27-I -'07	Pl. 229	7°18'	127°48'	6113	1.6	0.99	—
Min. temp. in situ 1°.57^5 at	17-V -'30	Sn. 263	6°46^5'	127°56'	3722	1.58^5	1.28	—
a depth of 3500 m. Mean	28-I -'07	Pl. 234	6°55'	126°44'	5330	1.6	1.10	—
value of sts. 263 and 265.	18-V -'30	Sn. 265	6°11^5'	126°55^5'	4853	1.68^5	1.24^5	—
	10-II -'75	Ch. 214	4°33'	127°06'	914	5.47		34.58
	22-V -'30	Sn. 269	4°36'	127°11^5'	534	7.42		34.57
	12-II -'75	Ch. 215	4°19'	130°15'	4663	1.89	1.47	34.70 34.46 34.57
	23-V -'30	Sn. 272	4°54^5'	129°12^5'	4660	1.67	1.25^5	34.66
			S.	E.				
Molukken sea.	13-X -'74	Ch. 196	0°48^5'	126°58^5'	1509	2.70		34.88
Min. temp. in situ 1°.84^5 at	1-X -'29	Sn. 81	1°05'	127°17^5'	1500	2.77		34.62
a depth of 2600 m. St. 347.								
			N.	E.				
	14-X -'74	Ch. 197	0°41'	126°37'	2195	2.17		34.98
	28-IX -'30	Sn. 347	0°58^5'	126°50'	2200	2.11^5		34.65
			S.	E.				
Ceram sea.	12-VI -'75	G. 102	2°54^5'	127°46^5'	3145	3.3	3.02	35.48
Min. temp. in situ 3°.03 at	8-IX -'30	Sn. 330	2°22^5'	128°00^5'	3150	3.03	2.75^5	34.61
a depth of 3125 m. St. 330.	13-VI -'75	G. 103	2°37^5'	129°19^5'	832	4.2		—
	7-IX -'30	Sn. 327	2°30'	128°48'	830	5.47		
	14-VI -'75	G. 104	2°42^5'	130°46'	1820	3.7		35.08 34.96
	6-IX -'30	Sn. 325	2°28^5'	129°50'	1820	3.31		34.61
	5-IX -'06	Pl. 186	1°53'	128°56'	958	4.9		34.61
	2-X -'29	Sn. 84	1°40^5'	128°48'	960	4.97		34.60^5
Banda sea.	28-IX -'74	Ch. 193	5°24'	130°37'	5121	3.31	2.77	34.66
Min. temp. in situ 3°.08 at	22-X -'30	Sn. 362	5°35'	130°56'	5120	3.29	2.75	34.60
a depth of 2800 m. Mean	3-X -'74	Ch. 195	4°21'	129°07'	2606	3.30		34.66
value of sts. 362 and 246.	22-IX -'30	Sn. 234	1°09^5'	125°18^5'	2600	3.11		34.61
	30-V -'75	G. 99	7°35'	125°27'	4243	2.9	2.50	35.08 34.56
	15-IV -'30	Sn. 246	6°57^5'	126°44'	4250	3.18	2.77	34.60
	31-V -'75	G. 100	6°33^5'	126°29^5'	4243	3.0	2.60	34.43 34.43
Aroe basin.	12-X -'29	Sn. 99	6°09^5'	133°39^5'	1460	3.99		—
Min. temp. in situ 3°.90^5 at	23-IX -'74	Ch. 191	5°41'	134°04^5'	1463	4.14		
a depth of 2275 m. Mean	13-X -'29	Sn. 104	5°02^5'	134°00'	1460	3.97		34.60^5
value of sts. 100 and 104.	12-X -'29	Sn. 100	5°53^5'	133°21^5'	1060	4.73		34.81
	24-IX -'74	Ch. 191*a*	5°26'	133°19'	1061	5.06		34.63
	13-X -'29	Sn. 101	5°44^5'	133°10'	1060	4.63^5		
Sawoe sea	12-V -'75	G. 96	9°56^5'	121°52'	2981	3.2	2.94	—
Min. temp. in situ 3°.39^5 at	8-XII -'29	Sn. 153	9°42'	121°53'	2987	3.41^5	3.16	
a depth of 2250 m. Mean value of sts. 153, 155 and 163.	13-V -'75	G. 97	9°58^5'	122°54^5'	3164	3.3	3.02	35.08 34.69^5
	9-XII -'29	Sn. 155	9°30^5'	122°42^5'	3190	3.43	3.13^5	34.59
	27-V -'75	G. 98	8°48'	124°15'	3758	3.3	2.94	—
	17-XII -'29	Sn. 163	8°51^5'	124°24^5'	3205	3.42^5	3.13	
Ind. Ocean.	8-V -'75	G. 94	12°27^5'	119°03^5'	5221	1.1	0.63	—
Min. temp. in situ 1°.15^5 at	24-IX -'29	Sn. 145	11°10'	119°17^5'	5230	1.25^5	0.78^5	
a depth of 4225 m. St. 145.	10-V -'75	G. 95	11°18^5'	120°08^5'	4078	1.1	0.77	—
	24-IX -'29	Sn. 145	11°10'	119°17^5'	4080	1.17^5	0.84^5	

In his research concerning the flow of the bottom water in the Pacific Ocean G. Wüst (6) very carefully examined the accuracy of the earlier observations. The „Challenger" observations were made with maximum and minimum thermometers (Six pattern) of which the capillary portion of the tube was not protected against pressure. According to Tait (7) the temperature readings would be 0°.03 C. too high for every 1000 m depth. For the observations carried out with max. and min. thermometers Wüst (6, p. 23) calculates a mean adiabatic rise of 0°.10 per 1000 m below the minimum level. For the „Challenger" observations this value would be slightly less, as the Six thermometers in use were very sensitive.

Let us now examine the „Challenger" observations from Table 2 *above* and *below* the minimum level separately. In Table 3 Tait's correction of minus 0°.03 C. per 1000 m was applied to the former, which brought the „Challenger" results into better agreement with those of the „Snellius", with the exception of Ch. St. 196. Owing to the comparatively small observation depths, however, the corrections are of less importance. In fact these values are slightly smaller, as Tait's correction was calculated for an observation temperature of about 10° C.

TABLE 3. Comparison of the „Snellius" observations with the bottom temperatures obtained by the „Challenger", *above* the minimum level and corrected for pressure on the thermometer.

Station	Depth of Obs. m	Temp. in situ °C	Corr. for pressure °C	Corrected Chall. temp. °C	Depth of minimum level m
Ch. 196	1509	2.70	—0.04^5	2.65^5	
Sn 81	1500	2.77			2600
Ch. 197	2195	2.17	—0.06^5	2.11^5	
Sn. 347	2200	2.11^5			2600
Ch. 195	2606	3.30	—0.08	3.22	
Sn. 234	2600	3.11			2800
Ch. 191	1463	4.14	—0.04^5	4.09^5	
Sn. 99	1460	3.99			2275
Ch. 191*a*	1061	5.06	—0.03	5.03	
Sn. 100	1060	4.73			2275

Table 4 shows the observations *below* the minimum level. The temperature *in situ* was corrected for compression of the thermometer, after which the mean adiabatic increase per 1000 m was calculated with reference to the depth of the minimum level and the minimum temperature *in situ* determined by the „Snellius". The results are rather divergent; for a *mean* rise per 1000 m we find 0°.06 C., after omitting st. 213. According to Wüst (6, p. 27) the rise should be something less than 0°.07 C. [1]) in the deep Pacific basins.

If, therefore, the full value of the adiabatic correction is applied for the calculation of the potential temperature, as is done in Table 2, and a good agreement is found with the „Snellius" observations, it is only accidental, because in that case the errors caused by pressure on the instrument (plus) and by the diminished adiabatic increase (minus) cancel each other. Whatever system of correction is applied to the „Challenger" temperatures we shall always find differences with the „Snellius" values. There are not only systematic errors, but accidental errors also. Sir. C. Wyville Thomson (8) states concerning the accuracy of the observations: *„I have no hesitation therefore in saying „that any single indication with a thermometer on Six's principle is not trustworthy, and that a fact in „temperature distribution can only be established by a series of corroborative determinations*".

[1]) 0°.10 minus 0°.03 C. See also Wüst (21).

TABLE 4. Comparison of the increase of the temperature in situ *below* the minimum level according to „Challenger"- and „Snellius"-observations.

Station	Depth of Obs.	Depth of minimum level	Min. temp. in situ	Temp. in situ	[1]) Corr. for pressure	Corrected Chall. temp.	Adiab. increase	Mean adiab increase per 1000 m
Ch. 202	4663			10.25	—0.14	10.11	0.03^5	0.01
Sn. 64	4070	1200	10.07^5	10.44^5				0.13
Ch. 211	4069			10.33	—0.12	10.21	0.13^5	0.05
Ch. 199	4755			3.72	—0.14	3.58	0.00^5	0.00
Sn. 57	4490	2500	3.57^5	3.75				0.09
Ch. 213	3749			3.61	—0.11	3.50	—	—
Sn. 57	3750	2500	3.57^5	3.68				0.08
Ch. 198	3931			3.83	—0.12	3.71	0.13^5	0.10
Sn. 53	3930	2500	3.57^5	3.69				0.08
Ch. 215	4663			1.89	—0.14	1.75	0.17^5	0.15
Sn. 272	4660	3500	1.57^5	1.67				0.08
Ch. 193	5121			3.31	—0.15	3.16	0.08	0.03^5
Sn. 362	5120	2800	3.08	3.29				0.09

Tait (7) mentions some imperfections of the thermometers used and remarks on p. 7: *„In fact, „the instruments cannot be said to do more than furnish rough and ready means of approximating to „temperatures within about a quarter of a degree, or in the most favourable circumstances, a tenth of a „degree Fahrenheit. Had they been more nearly what would be called „scientific" instruments, they might „have altogether failed on account of the rough treatment to which they were necessarily subjected during „use. Letting them down into the sea presents in general no great difficulties, but when they have to be „hauled on board again they are subject to jerks and shocks, and sometimes swing through large arcs at the „end of the lead line. Such misadventures are unavoidable at sea, and are excessively unfavourable to „accurate results, because the index is necessarily not fitted so tightly in the stem that it may not in a few „oscillations be sensibly displaced"*.

The „Gazelle" observations were also carried out with extreme thermometers. According to Wüst (6, p. 15) when tested under high pressure the thermometers did not display any conspicuous inaccuracies, so that it was not necessary to apply pressure corrections. All the same, the observations below the minimum level will be too low. Nothing can be deduced concerning the adiabatic increase from comparisons, it occurred more than once that below the minimum level temperatures were read which were lower than the minimum temperature observed by the „Snellius" in the basin. This could only be the case if the depth of the deepest threshold had decreased or if the temperature outside the inland sea had increased since the time of the „Gazelle" research.

The „Planet" observations were made with reversing thermometers. Wüst (6, p. 20) here distinguishes between the observations of 1906—1909, in which inacurracies were several times suspected, and those of 1909—1913, which can stand every possible test of precision. The bottom temperature of Pl. St. 186 only proves to be reliable.

B. Salinity. In Table 2 the salinity is included with the temperature, for comparison with the „Snellius" results.

From the „Challenger" Reports we have borrowed the areometer number, the readings of the instrument, the temperature at time of reading and the weight of the instrument. For the calculation of the volume Tables 3 and 4 of L. Möller (9) were used instead of Tables III and IV of Buchanan.

[1]) See remark stated above Table 3.

For determining the density σ_t the weight was divided by the corrected volume, as Buchanan's Table V showed some small inaccuracies. After this we determined the salinity from the density with Knudsen's Tables, subsequently calculating the density for the temperature *in situ* with Matthews Tables. In cases where the temperature and the salinity fell within the limits of the tables calculated by Mr. L. van Eyck for every 0°.01 C. and 0°.01‰ salinity, these were of course made use of. When circumstances permit they will be appended to the continuation of this part.

In L. Möller's work, referred to above, the author draws attention to the „Gazelle" observations and to the difference in salinity obtained by the areometer observations on board and the determinations of density made at Kiel. The latter only are included in Table 1; in Table 2 both values are given for comparison with the „Snellius" results. The water samples of the „Planet" were titrated in the usual way, for determining the Cl-content.

Let us now compare in Table 2, the salinity observations of previous researches and the results obtained by the „Snellius" at stations in the immediate neighbourhood, being supported by observations at higher levels.

In the *Sulu sea* the two values from the „Challenger" differ considerably from one another, which we do not consider to be possible in the deep water of this basin. The mean agrees with the „Snellius" results.

In the *Celebes sea* the salinity of Ch. St. 213 only corresponds to Sn. St. 57. The two other values are not trustworthy, a value of 34.25‰ at 4755 m is certainly too low, such a value is only found in the superficial layers of this basin. The high salinity observed at Ch. St. 198 is met with nowhere in the inland seas of the Archipelago near the bottom.

In the *Pacific Ocean* the value for Ch. St. 214 and the Sn. St. 269, close by, differ only insignificantly; at the same time there is a considerable difference in the level of observation. The three salinity values from Ch. St. 215 [1]) all differ from Sn. St. 272, for the first value the deviation is slight, considering the difference in method of determining the salinity. The „Snellius" value 34.66 was also found at depths of 3500, 4000, 4500 and 5000 m.

Considering the salinity observed in the Pacific at the depth of the „Snellius" ridge, the values of 34.88 and 34.98‰ seem to us much too high. Such values are not found near the bottom in the *Molukken sea.* The maximum near the bottom is 34.68‰.

In the *Ceram sea* near the bottom we found 34.61‰, a value which is supported by the „Planet". The values at the „Gazelle" stations 102 and 104, obtained from the density determinations on board and at Kiel, seem to us too high in connection with this.

A value of 34.66 from Ch. Sts. 193 and 195 was never found by us in the deep water of the *Banda sea.* At Sn. St. 362 the salinity varied between 34.62 to 34.58 at depths from 150 to 7000 m. Presumably the water sampler of Ch. Sts. 193 and 195 leaked. The samples were raised in a slip-water-bottle which was kept closed by a weight resting upon it. Wüst (10). The determination on board at G. St. 99 gives much too high a value, the one determined on shore is somewhat too low. The two determinations of G. St. 100 are certainly too low. Both stations were compared with Sn. St. 246.

In the *Aroe basin* the value of 34.81‰ is impossible in the bottom water; such a high value can originate neither from the Pacific nor from the Indian Ocean.

In the *Sawoe sea* the determination on board at G. St. 97 gives much too high a value; the determination at Kiel yields a value much nearer to that observed at Sn. St. 155.

Taken all together, therefore, it is only Ch. Sts. 213 and 214, Pl. St. 186 and the determination at Kiel of G. St. 99 which give a satisfactory agreement.

C. Oxygen. The bottom oxygen determinations of previous researches are very sparce; they are confined to two bottom observations of the „Challenger" at st. 199 in the Celebes sea and st. 211 in the Sulu sea.

Year, Date	Station	Position		Depth m	O_2 cc/L.
		Lat. N.	Long. E.		
22—X—'74	199	5°41′	123°34′	4755	3.21
28—I—'75	211	8°00′	121°42′	4069	4.36

[1]) The areometer was read three times at different temperatures.

For the depths given the O_2-content is certainly too high. A value of 3.21 was found by the „Snellius" in the neighbourhood of Ch. St. 199 at 300 m depth, while near the bottom 2.00 cc/L was observed. In the neighbourhood of Ch. St. 211 a value of 4.36 belongs to the surface layer above a depth of 50 m. In the deep water the „Snellius" observations yielled a much lower value.

Considering this and the results of the temperature and salinity comparisons, *it does not seem to me desirable to combine, in the area investigated, the results of previous researches with those of the „Snellius".*

III. DEPTHS OF OBSERVATION

For determination of the depth at which the botton observations were made we have at our disposal:

A. Readings of the protected and unprotected thermometers attached to the bottom water samplers. (Thermometer depths, T.D.).

B. Length of reeled in wire, indicated by the measuring wheel. (Wire depths, W.D.).

C. Echo soundings. (Echo depths, E.D.).

We will discuss these three methods of depth determination in succession.

A. **Thermometer depths.** — Hamaker (11) calculated a standard error of 4 m for the accuracy of the depth determinations, independent of the depth. If the bottom water sampler reversed a little too late the readings from the protected and unprotected thermometer will still give the correct depth of observation, as long as the thermometers function properly. By adding to *this depth* the length of the stray-line *we do not, however, obtain an accurate bottom depth.* If the reversing occurs much too late we can hardly speak of a *bottom* observation and to determine the bottom depth one of the other methods must be resorted to.

The thermometer depths were calculated by Hamaker (11) during the research and after the termination of the expedition again controled for possible zero changes of the thermometers; at the same time the results of the mutual comparison of the thermometers hanging at the same level in the serial observations were taken into consideration. Finally we investigated whether the thermometer depths fitted in with the temperature-depth curves and with the lowest serial observations. Fully 10% of the thermometer depths calculated were considered as erroneous or not to be relied upon. Cf. the notes printed below Table 5.

B. **Wire depths.** — For the average correction of the wire soundings minus 20 m has been mentioned by Pinke (12) when the soundings had been carried out under favourable conditions (standard error 15 m) [1]). Under unfavourable conditions the constant correction is equal to minus 45 to 50 m while a standard error of 37 m [2]) is given.

It is obvious that the amount of the differences between thermometer and wire depth will stand in relation to the conditions under which the soundings were carried out. This point has been considered by Pinke (12), but I think it desirable to return to it and calculate the mean differences and standard errors over again, making use now of all available material after a critical examination of *all* observations.

In relation to the conditions under which the wire soundings were made we proceed from the inclination of the wire visible above the sea surface. It is not only current, sea disturbance and wind that affect the inclination but no less the success with which the ship is handled. Consequently we arranged all available simultaneously determined wire and thermometer depths in groups in which the inclination of the visible part of the wire was about the same.

Before proceeding to this all temperature-depth, salinity-depth and temperature-salinity as well as a few density-depth curves were drawn. After this, with the aid of these curves we examined for each station separately whether discontinuities in the bottom observations pointed to an error in the depth of observation determined by the three above mentioned methods and which of the three depths fitted best to the serial observations.

---

[1]) Pinke actually calculated the standard error, but converts it to „probable error" by multiplying by 2/3.
[2]) Table XII (Pinke) gives 34.5 m.

Further we examined whether:

a. At some stations lying in or near straits or passages there was such a strong current that no conclusions could be drawn concerning the inclination correction from the difference between wire and thermometer depth.

b. The nature of the bottom indicated a strong bottom current.

c. During the wire sounding there had been much manoeuvring of the ship, according to the records.

d. The correct reading of the measuring wheel was doubtful.

At the conclusion of the notes to Table 5 (p. 24) will be found a record of the 17 stations where the thermometer depths are erroneous or not reliable owing to bottom samplers not reversing or not doing so in time, or the thermometers not functioning properly. 141 thermometer depths remained for comparison with the wire depths. Of the latter we have not used those made at stations 104, 130, 157, 163, 194, 199, 228, 285, 287, 291, 294, 296, 297, 299, 300, 303, 305, 339 341 and 372.

At st. 104 in the original record there is the remark „no wire depth", so that the high value later filled in is doubtful; at st. 157 the measuring wheel registered incorrectly and for st. 341 no wire depth was given. The remaining stations, considered less suitable for a comparison of wire and thermometer depths, lay either in or near straits or passages. Stations 303 and 305 in the Celebes sea form an exception to this, here the wire depth differs considerably from both the thermometer and echo depth. Finally no inclination of the wire was recorded for stations 137, 142, 155, 212 and 348*l*.

After omitting the above stations there remained 116. For these the mean difference between wire and thermometer depths was determined separately for an inclination of 0°, 5°, 10°, 15° and 20° or more. Under 5° one station was included that was marked 3°, under 10° two stations with 7° and 8° incline and under 15° one station with a wire inclination of 10° to 15°. The wire depths used are from column 13, Table I, Vol. II, Part 2, Ch. I. We then find:

Wire inclination	0°	5°	10°	15°	20° or more
Number of comparisons . .	46	36	23	8	3
Mean difference W.D.—T.D.	6	12	20	29	52 m
Standard error	16	19	14	26 m	

The mean differences plotted in fig. 1 give us a curve by which the following corrections were determined:

Inclination	0	2	4	6	8	10	12	14	16	18	20	degrees
Correction	6	8	11	14	17	20	24	27	31	38	52	m

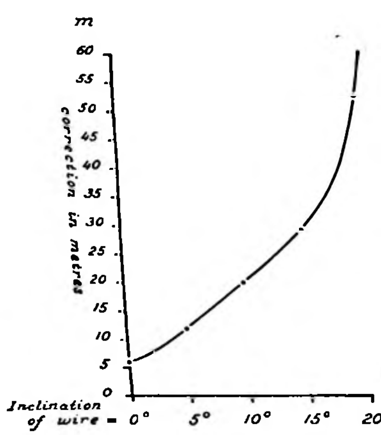


Fig. 1. Correction to be applied to wire depth for the inclination of the visible part of the wire.

If the mean differences be subtracted from the wire depth and the remaining differences be regarded as errors in the wire depths the above standard errors for the various wire inclinations separately are found. Independent of the inclination we calculated for 116 differences a total standard error of 17 m.

When a wire inclination of 0° was observed there is still a mean difference of 6 m. The manner of estimating the wire inclination was certainly not very satisfactory. At the same time by applying the inclination corrections we think that the value of the wire soundings is increased though the standard errors are considerable. It must not be forgotten that the corrections apply to the rather favourable conditions of weather and sea in the area of research.

The correction for 15° wire inclination agrees well with what Pinke (12) records on p. 66. The standard error of 34.5 m printed below Table XII (Pinke) is larger than what we calculated. The comparison, however, does not quite hold good as we compared the wire depths of 116 stations

corrected for the inclination of the wire with the thermometer depths, while Pinke considered the differences between corrected wire depths and „approximate" depths.

C. Echo depths. — On p. 24 of Vol. II, Part 2, Ch. I, Pinke states that the Atlas soundings are 35 m too high on an average. The differences calculated are those between thermometer depths and echo depths in Table VI and between „true depth" and echo depth in Table IX. On the same page we find for the standard error 37.5 m. Apparently this is the case under *favourable bottom conditions*. At the foot of Table IX the amount of 36 m is mentioned, which was determined from 20 differences, while we calculated a standard error of 39 m from the 77 comparions in Table VI. (Pinke).

There are in all 137 stations at which the conditions vary greatly. We will leave out of consideration the 8 stations 154, 167, 181, 196, 208, 236, 239 and 374 for which the differences are unusually great so that they must be attributed to abnormal circumstances [1]). For 129 stations, then, we find a mean difference between echo depth and thermometer depth of 35 m (as above) and a standard error of 43 m.

In consideration of the above a correction of minus 35 was applied to the echo depths; as this amount only applies to the Atlas sounder at „deep" the soundings less than 200 m were not corrected. The comparisons in Kaoe bay (depth about 500 m, flat bottom) gave a mean difference in smooth water of minus 13 m. In relation herewith for depths of 200 to 600 m we estimated a correction of minus 10 m.

The results may be summarised as follows:

Thermometer depths: No correction; standard error 4 m.

Wire depths: Constant correction dependent upon wire inclination; standard error for depths beyond 400 m 17 m.

Echo depths: Corrections 0, minus 10 and minus 35 m for depths less than 200 m, for 200—600 m and for more than 600 m respectively; standard error for depths greater than 400 m 43 m. No correction was applied for bottom inclination.

The observation depths calculated in this way are found in Table 5 *column* 10; the bottom depths corresponding to them are printed at the end of Vol. I, Ch. III. For determining the depths of observation near the bottom we used 148 wire soundings, 141 thermometer depths and 48 echo soundings.

EXPLANATION OF TABLE 5

Column 1. Date. *Column* 2. Number of station, a cross refers to the notes printed below the table. *Column* 3. Wire depth in metres, borrowed from column 8, Table I, Vol. II, Part 2, Ch. I. *Column* 4. Inclination of visible part of the wire. *Column* 5. Inclination correction. When the observation depth was less than 200 m no correction was applied for an inclination equal to zero. *Column* 6. Corrected wire depth. *Column* 7. Echo depth corrected as described above, founded upon column 17, Table I, Vol. II, Part 2, Ch. I. *Column* 8. Thermometer depth, i.e. the depth deduced from readings of the protected and unprotected thermometers, to which is applied a correction for the length of the stray-line. *Column* 9. Length of stray-line. *Column* 10. Depth at which the observation was made. *Column* 11. Method of depth determination used for determining the observation depth: D — wire depth. E — echo depth. T — thermometer depth.

In Table 5 all soundings are included for comparison of the results obtained with the three methods of depth determination. Several of these stations are not found in Table 36 [2]) on account of the absence of reliable oxygen bottom observations.

Considering the small standard error of the thermometer depths it was natural to use them in the first place for determining the depth of observation near the bottom. If no reliable thermometer depth was available use was not made of wire soundings in Straits and near islands where their was a strong current on account of the likelihood of incorrect estimation of the wire inclination and insufficient inclination correction.

In such cases we had resort to the echo depths, which on the other hand have the disadvantage that no correction was applied for the inclination of the sea floor. For 15 stations lying near a steep

[1]) At st. 208 the difference between thermometer depth and echo depth is equal to 325 m.
[2]) p. 71.

coast or bank, the maximum inclination of the sea floor on the spot was determined from the depth chart and the corresponding correction for bottom inclination was calculated. After applying this correction to the echo sounding the differences with the wire depth were considerably diminished. Yet the *uncorrected* echo depths, as far as could be ascertained, furnished a good agreement between the bottom observations and the serial observations in the temperature-depth curves, with the exception of sts. 42 (Borneo bank), 102 (coast of Aroe Islands), 195 (coast of island of Paloë) and 295 (coast of island of Miangas). Consequently the corrected *wire* depths are used for these last stations.

For further particulars we refer to the notes printed below the table.

TABLE 5. Depth of observation near the bottom deduced from thermometer, wire or echo depth.

Date		Station	Wire length reeled in	Inclination of wire	Correction for inclination	Corrected wire depth	Echo depth	Thermometer depth	Stray-line	Depth of observation	Depth deduced from:
1		2	3	4	5	6	7	8	9	10	11
1929											
July	27	25	61	0	0	61	60	—	5	56	D.
	28	26	81	0	0	81	76	—	5	76	D.
	28	27	61	0	0	61	56	—	5	56	D.
	29	28	70	0	0	70	75	—	5	65	D.
	29	29	689	0	6	683	659	—	31	652	D.
	30	30*	1851	0	6	1845	1771	—	31	1740	E.
	30	31*	2001	0	6	1995	1882	—	31	1851	E.
	30	32	628	0	6	622	600	—	31	591	D.
Aug.	2	33*	2081	20	52	2029	1932	—	31	1901	E.
	3	34*	1541	0	6	1535	1471	—	31	1440	E.
	3	35*	2173	0	6	2167	2003	—	31	1972	E.
	6	36*	1361	20/30	52	1309	1116	—	31	1085	E.
	7	37	56	0	0	56	55	—	5	51	D.
	7	38	1377	0	6	1371	1395	—	31	1340	D.
	7	39*a**	2288	0	6	2282	2164	—	31	2133	E.
	8	40	1156	5	12	1144	1128	—	31	1113	D.
	12	41*	2497	5	12	2485	2373	—	31	2342	E.
	12	42*	696	0	6	690	647	—	31	659	D.
	13	43*	2173	5	12	2161	2079	—	31	2048	E.
	13	44	406	0	6	400	408	—	31	369	D.
	18	45*I**	1141	10	20	1121	1088	—	31	1057	E.
	18	46	2094	0	6	2088	1992	—	31	2057	D.
	19	47*	5292	5/10	16	5276	5132	—	31	5101	E.
	20	48	5521	0	6	5515	5453	—	31	5484	D.
	21	49*	3113	0	6	3107	3010	—	31	2979	E.
	21	50	1788	0	6	1782	1713	—	31	1682	E.
	21	51	394	0	6	388	409	—	31	357	D.
	23	52	5023	0	6	5017	4999	—	31	4986	D.
	24	53	5010	0	6	5004	4999	—	31	4973	D.
	24	54*	3982	0	6	3976	3917	—	31	3886	E.
	25	55*	1104	0	6	1098	983	—	31	952	E.
Sept.	3	56	5015	0	6	5009	5028	—	31	4978	D.
	4	57*	4830	0	6	4824	4651	—	31	4620	E.
	5	58	2734	5	12	2722	2693	—	31	2691	D.

Date		Station	Wire length reeled in	Inclination of wire	Correction for inclination	Corrected wire depth	Echo depth	Thermometer depth	Stray-line	Depth of observation	Depth deduced from:
1		2	3	4	5	6	7	8	9	10	11
1929											
Sept.	5	59	550	0	6	544	577	—	31	513	D.
	5	60	90	0	0	90	97	—	5	85	D.
	5	61	81	0	0	81	86	—	5	76	D.
	6	62	472	10	20	452	458	—	31	421	D.
	6	63	3073	0	6	3067	3024	—	31	3036	D.
	6	64	4305	0	6	4299	4343	—	31	4268	D.
	7	65	3987	0	6	3981	3911	—	31	3950	D.
	7	66	4489	0	6	4483	4443	—	31	4452	
									61	4422	D.
									91	4392	
	8	67	1981	0	6	1975	1933	—	31	1944	D.
	8	68	195	—	—	195	228	—	31	197	E.
	8	69*	363	15	29	334	296	—	31	303	D.
	9	70*	126	10	20	106	125	—	31	94	E.
	9	71*	272	10	20	252	263	—	31	232	E.
	9	72*	224	10	20	204	198	—	31	167	E.
	17	73	1319	10	20	1299	1229	—	31	1268	D.
	18	74*	2700	5	12	2688	2637	—	31	2606	E.
	18	75	4785	5	12	4773	4823	—	31	4742	D.
	19	76*	—	—	—	—	5544	—	61	5483	E.
	21	77	2803	5	12	2791	2805	—	31	2760	D.
	21	78	1505	0	6	1499	1503	—	31	1468	D.
	22	79	2626	5	12	2614	2661	—	31	2583	D.
Oct.	1	80	4623	0	6	4617	4511	—	31	4586	D.
									61	4556	
	1	81	1672	0	6	1666	1666	—	31	1635	D.
	2	82	995	0	6	989	969	—	31	958	D.
	2	83*	406	0	6	400	378	—	31	347	E.
	2	84	1533	0	6	1527	1552	—	31	1496	D.
	2	85	685	0	6	679	648	—	31	648	D.
	3	86*	406	10	20	386	325	—	31	355	D.
	7	87*	511	5	12	499	436	—	31	405	E.
	7	88	564	0	6	558	514	—	31	527	D.
	7	89	1421	0	6	1415	1417	—	31	1384	D.
	7	90	1709	0	6	1703	1715	—	31	1672	D.
	7	91*	259	5	12	247	216	—	31	216	D.
	8	92*	694	5	12	6821	595	—	31	651	D.
	8	93*	1136	0	6	1130	1064	—	31	1033	E.
	9	94*	761	0	6	755	692	—	31	724	D.
	9	95	1831	0	6	1825	1812	—	31	1794	D.
	9	96	860	0	6	854	823	—	31	823	D.
	9	97	2332	0	6	2326	2345	—	31	2295	D.
	12	98	570	0	6	564	548	—	31	533	D.
	12	99*	1907	0	6	1901	1848	—	31	1817	E.
	12	100	3600	0	6	3594	3542	—	31	3563	D.

Date		Station	Wire length reeled in	Inclination of wire	Correction for inclination	Corrected wire depth	Echo depth	Thermometer depth	Stray-line	Depth of observation	Depth deduced from:
1		2	3	4	5	6	7	8	9	10	11
1929											
Oct.	13	101*	2244	0	6	2238	2139	—	31	2108	E.
	13	102	378	0	6	372	325	—	31	341	D.
	13	103	691	10	20	671	507	—	31	640	D.
	13	104*	3457?	0	6	3451?	3307	3296	31	3265	
									61	3235	T.
									91	3205	
	17	105	936	5	12	924	910	—	31	893	D.
	17	106	720	0	6	714	773	—	31	683	D.
	18	107	397	5	12	385	413	—	31	354	D.
	18	108	579	0	6	573	562	—	31	542	D.
	18	109	1510	0	6	1504	1490	—	31	1473	D.
	18	110	239	0	6	233	234	—	31	202	D.
	19	111*	563	0	6	557	528	—	31	526	D.
	19	112	1540	5	12	1528	1475	—	31	1497	D.
	24	113	647	10	20	627	764	—	31	596	D.
	24	114*	1541	10	20	1521	1437	—	31	1406	E.
	25	115	2085	7	15	2070	2047	—	31	2039	D.
	25	116	1821	5	12	1809	1855	—	31	1778	D.
	25	117*	602	10	20	582	553	—	31	522	E.
	26	118*	2919	0	6	2913	2843	—	31	2812	E.
	27	119	616	5	12	604	591	—	31	573	D.
	27	120*	2115	15	29	2086	1981	—	31	1950	E.
	27	121	2266	5	12	2254	2264	—	31	2223	D.
	28	122	1165	0	6	1159	1114	—	31	1128	D.
	28	123*	496	0	6	490	432	—	31	459	D.
	28	124l*	395	0	6	389	364	—	31	333	E.
	29	125	2615	0	6	2609	2581	—	31	2578	D.
	29	126*	429	10	20	409	368	—	31	378	D.
	29	127	2297	5	12	2285	2327	—	31	2254	D.
	30	128*	1446	0	6	1440	1435	—	31	1409	D.
	30	129*	437	5	12	425	378	—	31	394	D.
Nov.	8	130*	1930	0	6	1924	1851	1826	31	1795	T.
	8	131	2921	0	6	2915	2900	2901	31	2870	T.
	10	132	1319	0	6	1313	1299	1303	31	1272	T.
	13	133*	567	0	6	561	493	—	31	462	E.
	13	134	953	5	12	941	986	939	31	908	T.
	13	135	1156	8	17	1139	1162	1155	31	1124	T.
	13	136	379	5	12	367	378	—	31	336	D.
	16	137	484	—	—	—	422	440	31	409	T.
	16	138	959	10	20	939	928	946	31	915	T.
	16	139*	419	5	12	407	414	478?	31	376	D.
	17	140	1078	3	9	1069	1049	1071	31	1040	T.
	17	141*	1488	5	12	1476	1512	996?	31	1445	D.
	21	142*	1819	—	—	—	1899	1821	31	1790	T.
	22	143	1667	15	29	1638	1585	1641	31	1610	T.

Date		Station	Wire length reeled in	Inclination of wire	Correction for inclination	Corrected wire depth	Echo depth	Thermometer depth	Stray-line	Depth of observation	Depth deduced from:
1		2	3	4	5	6	7	8	9	10	11
1929											
Nov.	24	144	2775	0	6	2769	2814	—	31	2738	D.
	24	145	5714	0	6	5708	5764	5722	31	5691	
									61	5661	T.
									91	5631	
	25	146	5372	0	6	5366	5304	5371	31	5340	T.
	27	147	3650	0	6	3644	3663	3675	31	3644	T.
	27	148	1196	0	6	1190	1205	1201	31	1170	T.
Dec.	7	149	1366	0	6	1360	1372	1363	31	1332	T.
	7	150	203	0	0	203	213	—	31	172	D.
	7	151	943	20	52	891	908	896	31	865	T.
	8	152	1977	5	12	1965	1956	1918	31	1887	T.
	8	153	2946	8	17	2929	2965	2928	31	2897	T.
	9	154	1969	5	12	1957	2112	1976	31	1945	T.
	9	155	3331	—	—	—	3365	3298	31	3267	T.
	12	156	1889	10	20	1869	1844	1856	31	1825	T.
	12	156	1857	0	6	1851	1824	—	31	1820	D.
	13	157*	404	10	20	384	441	438	31	407	T.
	13	158	1988	10	20	1968	1940	1963	31	1932	T.
	13	159	3227	0	6	3221	3194	3250	31	3219	T.
	13	160	3227	5	12	3215	3174	3221	31	3190	T.
	16	161	985	10	20	965	1038	979	31	948	T.
	16	162	2025	10	20	2005	2070	2008	31	1977	T.
	17	163	3389	10	20	3369	3313	3296	31	3265	
									61	3235	T.
									91	3205	
	17	164	3897	5	12	3885	3777	3834	31	3803	T.
	21	165	437	0	6	431	407	435	31	404	T.
	21	166	2002	0	6	1996	2016	2002	31	1971	T.
	22	167	3435	0	6	3429	3545	3448	31	3417	T.
	22	168*	2641	0	6	2635	2559	—	31	2528	E.
	22	169*	661	0	6	655	576	—	31	545	E.
	23	170	1383	10	20	1363	1396	1361	31	1330	T.
1930											
Jan.	29	171	87	0	0	87	—	—	5	82	D.
	30	172*	726	5	12	714	739	—	21	693	D.
	30	173	1520	0	6	1514	1479	1511	33	1478	T.
	31	174	1228	5	12	1216	1221	—	33	1183	D.
	31	175*	2785	5	12	2773	2656	—	33	2623	E.
Febr.	1	176	660	15	29	631	619	637	33	604	T.
	4	177	1553	10	20	1533	1585	—	33	1500	D.
	5	178	2714	5	12	2702	2653	2726	33	2693	T.
	5	179	3968	5	12	3956	4038	3947	33	3914	T.
	5	180	5045	5	12	5033	5079	—	33	5000	

Date	Station	Wire length reeled in	Inclination of wire	Correction for inclination	Corrected wire depth	Echo depth	Thermometer depth	Stray-line	Depth of observation	Depth deduced from:
1	2	3	4	5	6	7	8	9	10	11
1930										
Febr.								63	4970	D.
								93	4940	
6	181	2825	5	12	2813	2703	2832	33	2799	T.
6	182	894	5	12	882	928	890	33	857	T.
7	182*l*	79	0	0	79	—	—	5	74	D.
10	183*	532	15	29	503	541	—	33	470	D.
11	184*	369	5	12	357	402	—	33	324	D.
13	185	632	5	12	620	624	—	33	587	D.
14	186*	1432	5	12	1420	1376	1401	33	1368	T.
14	187	3098	0	6	3092	3157	3098	33	3065	T.
15	188	1016	10	20	996	990	1023	33	990	T.
15	189	1866	0	6	1860	1878	1862	33	1829	T.
15	189*	1751	3	9	1742	1913	—	13	1729	D.
15	190	1410	5	12	1398	1439	1407	33	1374	T.
16	191	2032	0	6	2026	2010	1991	33	1958	T.
16	192	2617	20	52	2565	2536	2552	33	2519	T.
17	193	1676	0	6	1670	1739	1689	33	1656	T.
17	193*	1660	5	12	1648	1700	—	13	1635	D.
18	194*	2790	10	20	2770	2679	2691	33	2658	T.
19	195	533	15	29	504	476	—	33	471	D.
19	195*l**	1189	5	12	1177	1077	—	33	1044	E.
19	196	2222	5	12	2210	2017	2216	33	2183	T.
19	197*	5106	5	12	5094	5059	5133	33	5100	T.
20	198	2805	0	6	2799	2733	2804	33	2771	T.
23	199	837	0	6	831	758	790	33	757	T.
March 5	200	1154	15	29	1125	1081	1098	33	1065	T.
7	201	2961	5	12	2949	2910	2969	33	2936	T.
8	202*	3886	10/15	24	3862	3825	3898	33	3865	
								63	3835	T.
								93	3805	
8	203*	3521	10	20	3501	3452	3500	33	3467	T.
8	204	1509	0	6	1503	1458	1483	33	1450	T.
9	205	3926	0	6	3920	3967	3936	33	3903	
								63	3873	T.
								93	3843	
10	206	1229	5	12	1217	1250	—	33	1184	D.
12	207	1214	5	12	1202	1196	1186	33	1153	T.
13	208*	3560	5	12	3548	3196	3556	33	3523	T.
13	209*	4248	0	6	4242	4225	4133?	23	4202	
								53	4172	E.
								83	4142	
14	210	4919	5	12	4907	4871	4907	33	4874	T.
14	211*	2064	5	12	2052	2010	2025	33	1992	T.
15	212*	4937	10	20	4917	4994	—	33	4884	D.
15	212*	4970	—	—	—	4968	4968	10	4958	

Date	Station	Wire length reeled in	Inclination of wire	Correction for inclination	Corrected wire depth	Echo depth	Thermometer depth	Stray-line	Depth of observation	Depth deduced from:
1	2	3	4	5	6	7	8	9	10	11
1930 March								40	4928	T.
								10	4898	
16	213	1185	5	12	1173	1148	1135	33	1102	T.
16	214	3014	0	6	3008	3054	3002	33	2969	T.
17	215*	4709	5	12	4697	4716	3736?	33	4664	D.
17	216	3044	10	20	3024	3076	3017	33	2984	T.
17	217	1423	0	6	1417	1323	1422	33	1389	T.
20	218	4392	0	6	4386	4389	4404	33	4371	T.
21	219*	1208	10	20	1188	1129	—	33	1096	E.
22	220*	2614	10	20	2594	2585	—	33	2561	D.
22	221*	3656	0	6	3650	3669	3649	33	3616	T.
22	222*	1239	10	20	1219	1129	—	33	1096	E.
23	223	498	5	12	486	489	—	33	453	D.
24	224*	1129	15	29	1100	1037	1085	33	1052	T.
24	225	1963	15/25	52	1911	1894	—	33	1878	D.
24	226*	432	0	6	426	523	313?	33	393	D.
24	227	2962	5	12	2950	2924	2967	33	2934	T.
April 4	228*	2675	0	6	2669	2609	2590	33	2557	T.
5	229	5128	0	6	5122	5111	5133	33	5100	T.
5	230*	1427	10	20	1407	1367	1402	33	1369	T.
6	231	1110	5	12	1098	1133	1094	33	1061	T.
7	232	4581	5	12	4569	4618	4596	33	4563	T.
7	233	1805	0	6	1799	1733	1761	33	1728	T.
8	234*	3712	0	6	3706	3497	—	33	3464	E.
8	235	5035	0	6	5029	5021	—	33	4996	D.
9	236	3608	0	6	3602	3471	3597	33	3564	T.
9	237	3162	0	6	3156	3124	3168	33	3135	T.
11	239	1285	30	52	1233	1129	1236	33	1203	T.
11	240*	3136	0	6	3130	3295	—	33	3097	D.
12	241	4849	10	20	4829	4806	—	33	4796	D.
12	242	3361	10	20	3341	3323	—	33	3308	D.
13	243*	1228	0	6	1222	1129	—	33	1096	E.
14	244	2571	0	6	2565	2553	—	33	2532	D.
14	245	4429	0	6	4423	4451	—	33	4390	D.
15	246	4384	10	20	4364	4352	—	33	4331	D.
15	247	1525	0	6	1519	1496	—	33	1486	D.
16	248	2665	10	20	2645	2628	—	33	2612	D.
17	249*	4111	10	20	4091	4147	—	33	4058	D.
17	250	1039	5	12	1027	1013	—	33	994	D.
17	251	5084	0	6	5078	5110	—	33	5045	D.
18	252*	1569	15	29	1540	1414	—	33	1381	E.
18	253	4030	0	6	4024	4013	—	33	3991	
								63	3961	D.
								93	3931	

Date		Station	Wire length reeled in	Inclination of wire	Correction for inclination	Corrected wire depth	Echo depth	Thermometer depth	Stray-line	Depth of observation	Depth deduced from:
1		2	3	4	5	6	7	8	9	10	11
1930											
May	8	253l	951	10	20	931	910	—	33	898	D.
	9	255	3230	5	12	3218	3313	—	33	3185	D.
	10	256	1217	10	20	1197	1205	—	33	1164	D.
	10	257	2982	5	12	2970	2954	—	33	2937	D.
	13	260	7842	5	12	7830	8043	—	33	7797	D.
	15	261l	9883	0	6	9877	9791	—	33	9844	D.
	16	262*	10097	10/20	29	10068	9994	—	33	10035	D.
	17	263	3775	10	20	3755	—	—	33	3722	D.
	18	264*	9193	5	12	9181	9359	—	33	9148	D.
	18	265*	4995	10	20	4975	4886	—	33	4853	E.
	19	266*	2663	15	29	2634	2382	—	33	2349	E.
	19	267*	421	5	12	409	417	—	33	384	E.
	19	268*	794	5	12	782	715	—	33	749	D.
	22	269*	587	10	20	567	519	—	33	534	D.
	22	270	4723	5	12	4711	4490	—	33	4678	D.
	23	271	7852	0	6	7846	8002	—	33	7813	
									63	7783	D.
									93	7753	
	23	272*	5324	5	12	5312	5278	—	33	5279	D.
	25	275	5527	5	12	5515	5581	—	33	5482	D.
	26	276	4319	10	20	4299	4278	—	33	4266	D.
	27	277*	600	0	6	594	567	—	33	534	E.
	27	278*	480	0	6	474	500	—	33	441	D.
	27	278	497	0	6	491	519	—	30	461	
									60	431	D.
									90	401	
	27	279l*	499	0	6	493	504	—	10	483	D.
	27	280*	381	5	12	369	369	—	33	336	D.
	27	280	363	0	6	357	345	—	30	327	
									60	297	D.
									90	267	
	30	283	575	0	6	569	587	—	33	536	D.
	30	284	3690	0	6	3684	3663	—	33	3651	D.
	31	285	2083	20	52	2031	1971	1949	33	1916	T.
	31	286*	644	10/15	24	620	624	555?	33	591	E.
June	1	287	703	0	6	697	696	668	33	635	T.
	1	288	2220	0	6	2214	2244	2201	33	2168	T.
	12	289*	1589	10	20	1569	1547	1365?	33	1536	D.
	13	290	1155	5	12	1143	1129	—	33	1110	D.
	13	291*	2634	10	20	2614	2527	2517	33	2484	T.
	13	292	2503	15	29	2474	2494	2443	33	2410	T.
	16	293	853	0	6	847	773	847	33	814	T.
	16	294*	1905	5	12	1893	1903	1825	33	1792	T.
	16	295*	937	8	17	920	869	808?	33	887	D.
	18	296	3581	15/20	36	3545	3403	3322	33	3289	T.

Date	Station	Wire length reeled in	Inclination of wire	Correction for inclination	Corrected wire depth	Echo depth	Thermometer depth	Stray-line	Depth of observation	Depth deduced from:
1	2	3	4	5	6	7	8	9	10	11
1930										
18	297	2718	0	6	2712	2589	2541	33	2508	T.
19	298	831	0	6	825	816	806	33	773	T.
19	299*	1586	5	12	1574	1466	1495	33	1462	T.
19	300*	721	7	15	706	619	665	33	632	T.
23	301*	5183	5	12	5171	5129	3184?	33	5138	D.
24	303	4520	5	12	4508	4420	4419	33	4386	T.
25	305	3579	0	6	3573	3523	3507	33	3474	T.
July 4	309*l*	5147	10	20	5127	5061	5108	33	5075	
								63	5045	T.
								93	5015	
Aug. 31	320	2587	10	20	2567	2536	2564	33	2531	T.
Sept. 3	321*	6637	5	12	6625	6571	6426?	33	6592	D.
3	322	3335	5	12	3323	3385	3314	33	3281	T.
3	323*	502	0	6	496	557	441?	33	463	D.
4	324	2152	0	6	2146	2195	2139	33	2106	T.
6	325	2014	10	20	1994	2052	1996	33	1963	T.
7	326	492	10	20	472	465	474	33	441	T.
7	327	1452	10	20	1432	1415	1445	33	1412	T.
7	328	2960	5	12	2948	2907	2942	33	2909	T.
8	330*	4442	5	12	4430	4457	4450	30	4420	
								60	4390	T.
								90	4360	
19	331*	5010	0	6	5004	5112	5026	50	4976	
								300	4726	T.
								550	4476	
21	333	2722	10	20	2702	2708	2694	33	2661	T.
22	334	2669	0	6	2663	2683	2658	33	2625	T.
23	335*	2136	0	6	2130	2061	2241?	33	2097	D.
23	336	2380	0	6	2374	2314	2378	33	2345	T.
23	337*	3880	10	20	3860	3820	?	33	3827	D.
23	338	1787	5	12	1775	1807	—	33	1742	D.
23	339*	544	15	29	515	461	398	33	365	T.
24	340	2520	10	20	2500	2514	2510	33	2477	T.
26	341*	—	—	—	—	—	1305	20	1285	T.
								100	1205	
27	343*	1205	10	20	1185	1274	2100?	33	1152	D.
27	344	2501	10	20	2481	2489	2479	33	2446	T.
27	345	2788	10	20	2768	2668	2736	33	2703	T.
27	346	501	5	12	489	432	492	33	459	T.
28	347*	3062	5	12	3050	3030	3061	50	3011	
								300	2761	T.
								550	2511	

Date		Station	Wire length reeled in	Inclination of wire	Correction for inclination	Corrected wire depth	Echo depth	Thermometer depth	Stray-line	Depth of observation	Depth deduced from:
1		2	3	4	5	6	7	8	9	10	11
1930											
Oct.	1	348*l**	2218	—	—	—	2198	2198	25	2173	
									125	2073	T.
									225	1973	
	3	350	2592	0	6	2586	2588	2558	33	2525	T.
	3	351	789	10	20	769	721	788	33	755	T.
	3	352	1048	10	20	1028	1010	1018	33	985	T.
	4	353	1877	5	12	1865	1904	1872	33	1839	T.
	6	354	592	5	12	580	543	579	33	546	T.
	6	354*a*	1364	0	6	1358	1319	1365	33	1332	T.
	8	355	2046	0	6	2040	1974	2049	33	2016	T.
	11	357	1582	0	6	1576	1565	1579	33	1546	T.
	11	358*	4463	0	6	4457	4430	4467	50	4417	
									550	3917	T.
									1050	3417	
									1550	2917	
	11	359	3552	5	12	3540	3541	3549	33	3516	T.
	12	360*	1105	5	12	1093	1015	1142?	33	1060	D.
	12	361	2624	0	6	2618	2597	2629	33	2596	T.
	22	362	7346	10	20	7326	7314	—	33	7293	
									63	7263	D.
									93	7233	
	23	363	930	0	6	924	950	898	33	865	T.
	23	364	1077	15	29	1048	1071	1071	33	1038	T.
	24	364*a**	4451	0	6	4445	4435	4435	40	4395	
									900	3535	T.
									1400	3035	
	25	365	6326	0	6	6320	6342	6313	33	6280	T.
	26	368	2454	0	6	2448	2463	2451	33	2418	T.
	27	369	4474	5	12	4462	4510	4468	33	4435	T.
	28	370*	1703	0	6	1697	1709	1685	33	1652	T.
	29	372*	988	5	12	976	921	940	33	907	T.
	30	373*	4078	10	20	4058	4085	2693?	33	4025	D.
Nov.	1	374*	2525	5	12	2513	2610	2509	50	2459	
									250	2259	T.
									750	1759	
	1	375	1432	5	12	1420	1444	1422	33	1389	T.
	2	376	3308	0	6	3302	3308	3292	33	3259	T.
	3	377	3376	5	12	3364	3383	3347	33	3314	T.
	4	379*	3326	0	6	3320	3286	—	10	3310	D.
	4	380*	3318	0	6	3312	3326	2392?	33	3279	D.
	5	381	1057	15	29	1028	995	1016	33	983	T.
	11	382*	3509	5	12	3497	3482	3492	100	3392	
									500	2992	T.
									1000	2492	

NOTES TO TABLE 5

In these notes the following abbreviations were used:
T.D. curve — temperature-depth curve.
S.D. curve — salinity-depth curve.
Th.D. — thermometer depth.
W.D. — wire depth.
E.D. — echo depth.

St. 30. The corrected wire sounding gave a depth of 1845 m with a wire inclination of 0°. Considering the strong current in Makassar strait preference was given to the echo sounding. *St. 31.* The same applies to st. 31, the effect of the current upon the wire inclination will have been strong all along in the Strait. *St. 33.* Probably the wire inclined over a great length. *St. 34.* Most probably inclination will have been more than 0° below the surface so that wire depth is not considered very reliable. *St. 35.* The same applies to st. 35. Current 2 seamiles. *St. 36.* Here where there was a strong surface current the ship was held in place for an experiment by slowly steaming ahead. Consequently the wire had a considerable inclination so that preference was given to the echo sounding. *St. 39a.* Probably the inclination was more than 0° below the surface. *St. 41.* Probably the wire inclined over a great length. *St. 42.* W.D. preferred in connection with T.D. curve. *St. 43.* At the northern entrance to Makassar strait the strong current would cause the wire to incline down to a great depth. *St. 45l.* This was probably the case at st. 45*l* also. *St. 47.* Surface current 3 seamiles. The wire chafed against the side of the ship so that the inclination correction may be too small. *St. 49.* The wire inclination below sea level was probably more than 0°. *St. 50.* As st. 49. Probably inclination below surface near the coast was more than 0°. *Sts. 54 and 55.* Near the coast of Celebes wire inclination below surface probably more than 0°. *St. 57.* Wire snapped at joint during reeling in. *St. 69.* W.D. preferred in connection with T.D. curve. *Sts. 70, 71 and 72.* These stations lie in Sibutu strait where strong currents occur. Preference given to echo depth. *St. 74.* Wire probably inclines also at deeper levels. *St. 76.* No reliable wire sounding. *St. 83.* In entrance to Halmahera sea; considering current preference was given to echo depth. *St. 86.* W.D. instead of E.D. in connection with S.D. curve. *St. 87.* Probably more effect of the current in deeper layers near the coast. *St. 91.* W.D. instead of E.D. in connection with S.D. curve. *St. 92.* W.D. instead of E.D. in connection with T.D. curve. *St. 93.* Wire inclination below sea level probably more than 0°; wire deviates rapidly after 90 m was paid out. *St. 94.* W.D. instead of E.D. in connection with T.D. curve. *St. 99.* As st. 93. *St. 101.* Probably more effect of the current near the coast. *St. 104.* W.D. doubtful. *St. 111.* W.D. preferred in connection with T.D. curve. *St. 114.* In Strait between the islands of Babar and Sermata, preference was given to echo sounding. *St. 117.* Wire probably inclines also at greater depth. *St. 118.* Inclination below sea level probably more than 0°. Echo depth deduced from observations carried out by 6 observers. *St. 120.* Inclination correction probably insufficient. *St. 123.* W.D. preferred in connection with T.D. curve. *St. 124 l.* Inclination below sea level probably more than 0°. Heavy sounding tube 100 kg. *St. 126.* W.D. preferred in connection with T.D. curve. *St. 128.* Heavy sounding tube 140 kg. *St. 129.* W.D. preferred in connection with T.D. curve. *St. 130.* When 400 m was paid out the wire deviates rapidly. *St. 133.* In Sawoe strait near coast, strong current. *St. 142.* Wire inclination unknown. *St. 157.* Measuring wheel probably incorrectly read. *St. 168.* Inclination below sea level probably more than 0°. *St. 169.* Probably more effect of the current near the coast and more inclination than 0°, below the surface. *St. 172.* Wire snapped, observation repeated. *St. 175.* In passage between Flores and Bali sea. Effect of the current, down to great depth. *Sts. 183 and 184.* Bad weather. *St. 186.* Strong current, probably effect on inclination in deeper layers. *Sts. 189 and 193.* Heavy sounding tube, 140 kg. *Sts. 194 and 195 l.* Strong current. *St. 197.* When 50 to 60 m was paid out the wire deviates rapidly. *Sts. 202 and 203.* Strong current. *St. 203.* At 100 to 150 m wire deviates rapidly. *St. 208.* At 500 m wire deviates rapidly *St. 209.* Heavy weight, 60 kg. *St. 211.* Much manoeuvring. *St. 212.* Heavy weight on wire of serial winch. No wire inclination recorded. Also sounding with ordinary sounding tube. *St. 219 and 222.* In Sanana strait. Probably more effect of the current on the inclination at greater depth. *St. 220.* Strong current. *St. 221.* Much manoeuvring. *St. 224.* In Lifamatola strait, much manoeuvring. *St. 228.* Near Lifamatola strait, much manoeuvring. *St. 230.* Much manoeuvring. *St. 234.* Wire inclination below sea level probably greater than 0°. *St. 240.* Wire snapped. *St. 243.* Probably more influence of the current near the coast of island of Damar. Wire snapped. *St. 249.* Wire deviates rapidly when 800 m was paid out. *St. 252.* Effect of current at greater depths near south coast of Boeroe. *St. 262.* Echo depth deduced from observations carried out by 11 observers. *St. 264.* Wire deviates rapidly at 200 to 300 m. *Sts. 265, 266 and 267.* In the strait south of the island of Mindanao. Strong current. Pre-

ference given to echo sounding. *St. 266*. Wire deviates rapidly at 100 to 200 m. *Sts. 268 and 269*. W.D. preferred in connection with T.D. curve. *St. 272*. Wire snapped. *St. 277*. Wire inclination below sea level probably more than 0°. *St. 278*. Heavy sounding tube, 120 kg. *St. 279l*. Bottom sampler only. *St. 280*. Heavy (100 kg) and ordinary sounding tubes. *St. 286*. Wire inclination uncertain. Effect of current near south point of Talaud islands at greater depth. *St. 291*. Much manoeuvring. Inclination correction possibly too small. *St. 294*. In Straits south of Mindanao, strong current. At 300 m the wire deviates rapidly. *St. 299*. Current 2 seamiles. Second sounding at 8 a.m. omitted on account of great inclination of wire, while no T.D. available. *St. 300*. Strong current. *Sts. 330 and 331*. Heavy sounding tube, 140 kg. Tension at beginning of reeling in 500 to 550 kg. *St. 339*. Near coast strong current. Probably great wire inclination to considerable depth. *St. 341*. Heavy weight, 60 kg. *St. 347*. Heavy sounding tube, 140 kg. *St. 348 l*. Heavy weight on wire of serial winch. *St. 358*. Heavy sounding tube, 160 kg. Near coast of Ceram, current 1.5 seamiles. *St. 364a*. Heavy sounding tube, 160 kg. *St. 370*. In Strait west of island of Babar. *St. 372*. Near the island of South Terbang. Inclination correction certainly too small. *Sts. 374, 379 and 382*. Heavy sounding tube, 160 kg. *Sts. 139, 141, 209, 215, 226, 286, 289, 295, 301, 321, 323, 335, 337, 343, 360, 373 and 380*. Thermometer depths erroneous or not reliable.

IV. OXYGEN OBSERVATIONS

The oxygen material consists only of the bottom observations of the Snellius-expedition. *The results of the observations, reduced to* 0° *C. and a pressure of* 1013 *mbar are entered in Table* 36[1]). Where a correction of + 0.1 cc/L has been applied to the oxygen determination the result is printed in bold type.

A. Seasonal variations and accuracy of the observations. — We will now discuss the various errors in the oxygen observations in succession, while including the changes in the O_2-content due to long- and short-period fluctuations (temporal variations). This will enable us to conclude to what depth the bottom observations, which were made *at different times*, can be combined for the construction of a representation of the oxygen distribution in the bottom water (Pl. I) and what value may be attached to this representation.

The following sources of error must be taken into consideration:

a. Seasonal variations and those from one year to another.
b. Internal waves.
c. Titration errors.
d. Errors in determination of the depth of observation.
e. Errors in location of the ship.

TABLE 6. Celebes sea.

Interval 9 months				Interval 10 months			
Depth m	O_2 cc/L			Depth m	O_2 cc/L		
	St. 75	St. 304	Δ		St. 56	St. 302	Δ
50	4.61	4.69	—.08	480	1.96	2.58	—.62
100	4.03	4.18	—.15	950	2.19	2.25	—.06
150	3.80	3.79	—.01	1200	2.14	2.10	—.04
200	3.71	3.42	.29	1450	2.14	2.18	—.04
250	3.58	3.27	.31	1950	2.17	2.19	—.02
300	3.22	2.86	.36	2450	2.15	2.17	—.02
400	2.38	2.56	—.22	3000	2.16	2.15	.01
500	2.17	2.32	—.15				
600	2.31	2.41	—.10				
800	2.21	2.46	—.25				
1000	2.22	2.19	—.03				
1250	2.19	2.21	—.02				
1500	2.18	2.21	—.03				
1750	2.16	2.31	—.15				
2000	2.18	2.36	—.18				
2500	2.10	2.16	—.06				
3000	2.08	2.17	—.09				

[1]) p. 71.

Finally we shall treat separately the inaccuracy of the bottom determinations due to oxidation of the inside of the bottom samplers during the earlier stages of the research.

a. Seasonal fluctuations and those from one year to another.

When the ship returned to the same area after the lapse of some time, the observations were partially or entirely repeated in the vicinity of some of the stations. This method threw valuable light upon the changes which take place in the properties of the sea water at various levels.

Our material is limited, being confined to the areas and stations below, the position of the latter will be found on the route charts and on p. 145 of Vol. I.

The differences between the observations at sts. 75 and 304 [1]) are greatest between 200 and 400 m after which they become less significant. The O_2-content at st. 304 at 1750 m and 2000 m is probably too high, at any rate it deviates considerably from the mean value at these depths, calculated for the Celebes sea [2]).

In the same basin we are able to compare also the observations at sts. 56 and 302 after a time interval of 10 months. At 950 m and deeper levels the differences are very slight. The almost constant amount of oxygen between 1450 and 3000 m at both stations also indicate that the O_2-contents at st. 304 at 1750 and 2000 m are probably too high. The above data show that most of the changes recorded in the Celebes sea after a lapse of 9 to 10 months are less than 0.1 cc/L below the niveau of 1000 m.

TABLE 7. Makassar strait.

Interval about 1 year.

Depth m	O_2 cc/L St. 39	O_2 cc/L St. 311	Δ	Depth m	O_2 cc/L St. 41	O_2 cc/L St. 310	Δ
50	4.18	4.25	—.07	50	4.55	4.50	.05
100	3.77	3.77	.00	100	3.56	3.94	—.38
150	3.35	3.54	—.19	200	3.19	3.07	.12
200	3.15	3.48	—.33	300	2.74	2.72	.02
250	2.87	3.06	—.19	500	2.35	2.30	.05
300	2.64	2.86	—.22	800	2.21	2.25	—.04
400	2.30	2.33	—.03	1000	2.15	2.13	.02
500	2.25	2.29	—.04	1250	2.02	2.08	—.06
600	2.24	2.25	—.01	1500	2.13	2.11	.02
800	2.17	2.20	—.03	2000	2.14	2.14	.00
1000	2.10	2.13	—.03				
1250	2.05	2.05	.00				
1500	2.04	2.04	.00				
2000	2.07	2.07	.00				

The interval between the observations at sts. 41 and 310 and at 39 and 311 is about a year. The changes at the latter stations are considerable at 150 to 300 m while at other depths they are very slight. The comparison between the more northerly stations 41 and 310 also indicates only small differences below the depth of 300 m.

In the northern area of the Molukken sea [3]) opposite Biaro strait observations were made with an interval of one year, at sts. 79 and 342 which lie at almost the same spot. At nearly every level the O_2-content is increased. The greatest difference is found at 100 to 200 m depth diminishing downwards to zero at 800 m, still at 1000 and 1250 m the change is more than 0.10 cc/L. Probably at these levels the deep water flowing from the south, in 1930 penetrates further north than in 1929.

[1]) Table 6.
[2]) p. 27.
[3]) Table 8.

TABLE 8. Molukken sea, North.

Depth m	O₂ cc/L		
	Interval 1 year		
	St. 79	St. 342	Δ
50	4.60	4.41	.19
100	3.66	3.95	—.29
150	3.21	3.68	—.47
200	3.03	3.30	—.27
300	2.64	2.80	—.16
400	2.50	2.63	—.13
500	2.31	2.55	—.24
600	2.40	2.50	—.10
800	2.42	2.42	.00
1000	2.17	2.31	—.14
1250	2.23	2.41	—.18
1500	2.42	2.48	—.06

TABLE 9. Molukken sea, South. (Batjan trough).

Depth m	O₂ cc/L		
	Interval 1 year		
	St. 80	St. 332	Δ
50	4.55	4.25	.30
125	3.47	3.60	—.13
175	2.96	3.43	—.47
250	2.75	2.93	—.18
400	2.64	2.65	—.01
500	2.61		
600	2.50		
800	2.38		
1000	2.38		
1250	2.40		
1500	2.47	2.59	—.12
2000	2.56	2.75	—.19

In the southern area of the Molukken sea we possess only a partial repetition of the observations at st. 80 in the Batjan trough. Here too the O_2-contents appear to have increased in the course of a year. The greatest change is found at 175 m, but in the deeper layers too, as in the north of the Molukken sea considerable changes were observed. As we shall see later [1] the Pacific deep water flows southwards, east of the central ridge in the Molukken sea. Probably this water in definite layers extends further or less far eastwards at different times.

In the northern area of the Ceram sea [2] near the southern entrance to the Halmahera sea we are able to compare observations to 1000 m depth at an interval of 11 months. Important changes take place in the uppermost water layers and even at 400 m the difference is considerable. At st. 329 the O_2-content declines gradually with the depth, while st. 84 shows a slight increase at 400 m. Otherwise the changes are small.

TABLE 10. Ceram sea.

Depth m	O₂ cc/L		
	Interval 11 months		
	St. 84	St. 329	Δ
50	4.09	3.71	.38
100	3.62	3.35	.27
150	3.21	3.10	.11
200	2.95	2.96	—.01
300	2.73	2.72	.01
400	2.76	2.60	.16
600	2.62	2.57	.05
800	2.49	2.51	—.02
1000	2.45	2.45	.00

[1]) p. 49.
[2]) Table 10.

TABLE 11. Banda sea, North.

Depth m	Interval 6 months O₂ cc/L St. 212	St. 331	Δ
50	4.57	4.64	—.07
100	3.41	3.16	.25
150	2.85	2.97	—.12
200	2.74	2.85	—.11
300	2.52	2.63	—.11
400	2.59	2.49	.10
600	2.45	2.37	.08
800	2.44	2.35	—.09
1000	2.39	2.38	.01

TABLE 12. Banda sea, South.

Depth m	Interval 5 months O₂ cc/L St. 235	St. 319	Δ
50	4.52	4.04	.48
100	3.49	2.93	.56
200	2.65	2.75	—.10
300	2.47	2.59	—.12
400	2.41	2.46	—.05
600	2.30	2.31	—.01
1000	2.22	2.31	—.09

In the Northern and Southern Banda sea we possess a partial repetition of the observations at sts. 212 and 235 to 1000 m depth, after an interval of about a year. In the northern area the changes below 400 m are less than 0.10 cc/L, in the southern area this is the case below 300 m. As in the Ceram sea at st. 212 we find a slight rise in the O_2-content at 400 m while at st. 331 the change with the depth runs regularly.

TABLE 13. Flores sea.

Depth m	Interval 6 months O₂ cc/L St. 181	St. 314	Δ
50	3.84	4.50	—.66
100	3.48	4.17	—.69
150	3.38	3.24	.14
200	3.10	2.93	.17
300	2.49	2.43	.06
400	2.31	2.28	.03
600	2.23	2.22	.01
1000	2.13	2.14	—.01
1500	2.20	2.24	—.04
1750	2.22	2.22	.00

After a period of 6 months the observations in the Flores sea [1]) at st. 181 to a depth of 1750 m were repeated at st. 314. The changes are only of importance in the upper layers, below 300 m the differences are slight.

[1]) Table 13.

TABLE 14. Sawoe sea.

Interval 1 year.			
Depth m	O_2 cc/L		
	St. 155	St. 379	Δ
50	4.73	3.56	.17
100	3.49	3.30	.19
125	3.28	3.07	.21
150	3.16	2.94	.22
175	2.93	2.89	.04
200	2.75	2.81	—.06
250	2.47	2.49	—.02
300	2.43	2.45	—.02
400	2.24	2.23	.01
1000	2.22	2.31	—.09

The observations at st. 155 in the Sawoe sea were repeated at st. 379 after about a year at 50 to 400 m and at 1000 m. Below 150 m the observed differences are unimportant, but at 1000 m the change again increases.

b. Internal waves.

The differences recorded above will not be due to seasonal fluctuations or annual changes only. The short-period fluctuations, caused by internal waves, will also effect them. For examining their influence we have at our disposal the repeated serial observations from the anchor stations 39*a* and 253*a*, the former lying in Makassar strait, the latter in Lifamatola strait, which connects the Molukken sea with the Ceram sea.

For st. 39*a* Lek (13) gives a *maximum* fluctuation of 0.33 cc/L at a depth of 250 m and for Lifamatola strait at:

450 m	0.20 cc/L
800 m	0.05 cc/L

From the repeated serial observations at the anchor stations Hamaker (11 p. 38) deduces from the standard error of the temperature due to internal waves the corresponding vertical displacement of the water layers of

25 m at a depth of 400 m
33 „ „ „ „ „ 500 „
31 „ „ „ „ „ 600 „
20 „ „ „ „ „ 800 „

To determine the corresponding changes in the O_2-contents from this standard displacement we calculate the mean vertical O_2-distribution for the neighbouring areas of the two oceans and the large basins Sulu sea, Celebes sea and Banda sea, from the observations at the following stations.

A. *Pacific Ocean.* Sts. 264, 265, 270, 271 (260), 272, 273, 275, 276, 287 and 288.
B. *Indian Ocean.* Sts. 131, 144, 145, 146 and 147.
C. *Sulu sea.* Sts. 63, 64, 65, 66 and 67.
D. *Celebes sea.* Sts. 47, 48, 52, 53, 56, 57, 75, 76, 301, 302, 303 and 304.
E. *Banda sea, north.* Sts. 209, 210, 212, 215, 218 and 331.

TABLE 15. Mean oxygen content.

Depth m	A	B	C	D	E	Depth m	A	B	C	D	E
25				4.52		1000	2.23	2.23	1.56	2.19	2.37
50	4.47	4.58	4.40	4.47	4.53	1500	2.39	2.58	1.44	2.19	2.38
75	4.08					2000	2.65	3.12	1.47	2.16	2.41
100	3.76	3.29	2.80	4.07	3.58	2500	3.01	3.45	1.56	2.16	2.45
150	3.50	2.79	1.93	3.76	2.90	3000	3.30	3.67	1.57	2.14	2.48
200	3.36	2.63	1.77	3.49	2.75	3500	3.41	3.93	1.63	2.13	2.48
250	3.26	2.50	1.61	3.20	2.61	4000	3.44	4.22	1.62	2.07	2.47
300	2.95	2.38	1.53	2.91	2.58	5000	3.44	4.28		2.00	2.47
400	2.89	2.17	1.58	2.44	2.60	6000	3.42				
500	2.70	2.10	1.63	2.38	2.49	7000	3.42				
600	2.60	2.07	1.62	2.42	2.40	8000	3.45				
800	2.36	2.11	1.57	2.31	2.37	10000	3.39				

From these data oxygen-depth curves were constructed, from which the oxygen gradient for a depth interval of 40 m was determined at various levels. The results are given in the following table.

TABLE 16. Vertical change of the O_2-content per 40 m at various depths in 10^{-2} cc/L.

Area	Depth m									
	100	200	300	400	500	600	800	1000	1500	2000
Pacific Ocean	— 35	— 8	—11	—5	—7	—4	—3	0	+2	+2
Ind. Ocean	—110	—12	— 9	—6	—2	0	+2	+4	+5	+3
Sulu sea.	—130	—12	0	+3	0	—2	0	—1	0	0
Celebes sea	— 28	—24	—20	—10	0	0	—3	+1	0	0
Banda sea	— 80	—10	0	0	—5	—1	0	0	0	0

Although Hamaker's data concerning the vertical displacement of the water layers only serve as averages from the entire area, they enable us to estimate the change in O_2-content accompanying them, by making use of the gradient data in table 16. We then find:

TABLE 17. Standard error in the O_2-content due to internal waves in 10^{-2} cc/L.

Area	Depth m			
	400	500	600	800
Pacific Ocean	3	6	3	2
Indian Ocean	4	2	0	2
Sulu sea.	2	0	2	0
Celebes sea	6	0	0	2
Banda sea	0	4	1	0
Mean	3.0	2.4	1.2	1.2

As the standard vertical displacement in the vicinity of the bottom will be less than that in a free water layer at the same level, the standard errors in the *bottom* oxygen content, due to internal waves, will remain below the values from Table 17. See also footnote 1) on page 31.

From what has been said above about the temporal variations, it appears that the changes below a depth of 600 m only very occasionally exceed 0.10 cc/L. The standard error of the O_2-content due to internal waves at this depth is at most 0.03 cc/L. (Pacific Ocean).

c. Accuracy of the oxygen titrations. Hardon (14, p. 54) gives the frequency of the deviations of the single titrations as compared to the mean of two titrations. From these deviations a standard error follows of 0.02 cc/L for the *mean value.*

d. Errors in the depths of observation.

The standard error of the depth determinations was discussed on p. 11—13. If the mean of the values found by Pinke (12) and the present author are taken for the wire and echo depths we find for the standard error:

thermometer depth	4 m
wire depth	25 m
echo depth	40 m

The effect of the standard error calculated by Hamaker (11, p. 35) for the thermometer depths may be neglected for the bottom observations. In judging the accuracy of the depths of observations determined by the two other methods, we must not forget that these depths were obtained by applying a correction to the bottom depths equal to the length of the stray-line. Here it is, therefore, assumed that the bottom sampler did actually reverse at a distance from the sea floor equal to the length of the stray-line, which will not invariably have been the case, as the slack in the stray-line is not always the same. It even sometimes occurred that the bottom water sampler touched the bottom. Moreover the moment of reversing depends upon the correct working of the reversing mechanism. Too much value must, therefore, not be attached to 25 m and 40 m as standard errors for the *depths of observation.*

For determining the corresponding changes in the oxygen content we will use Table 16 and confine ourselves to depths of 400, 500, 600 and 800 m. [1]).

TABLE 18. Standard error in the O_2-content due to errors in depth determination in 10^{-2} cc/L.

Area	Wire depth m				Echo depth m			
	400	500	600	800	400	500	600	800
Pacific Ocean	3	4	3	2	5	7	4	3
Indian Ocean	4	1	0	1	6	2	0	2
Sulu sea.	2	0	1	0	3	0	2	0
Celebes sea	6	0	0	2	10	0	0	3
Banda sea	0	3	1	0	0	5	1	0
Mean	3.0	1.6	1.0	1.0	4.8	2.8	1.4	1.6

e. Errors in the position of the ship.

In accordance with Pinke (12, p. 31) these errors, appear to be so slight that the inaccuracies they might give rise to in the O_2-content are negligeable compared to the other sources of error. Hamaker (11, p. 39) arrived at the same conclusion, when analysing the temperature observations. The horizontal O_2-gradient in the greatest part of the area is very small and where it becomes more emphasized in the shallower depths the effect of the internal waves prevents an accurate analysis.

At a depth of less than 600 m the total standard error (S) of *b*, *c* and *d* ($S = \sqrt{S_b^2 + S_c^2 + S_d^2}$) is mostly considerably smaller than seasonal and annual fluctuations [2]). In discussing the oxygen distribution in the bottom water, therefore, we must take in the first instance these fluctuations into consideration.

Below 600 m the seasonal fluctuations are, for the greater part, so small that it is practically impossible for them to affect the representation of the O_2-distribution. Consequently for the construction of Plate I we used only the observations at depths of 600 m or more, while in Table 36 all available data are included.

[1]) Supposing that the vertical gradient near the bottom does not differ from that in a free water layer at the same level.

[2]) At 600 m $\sqrt{S_b^2 + S_c^2 + S_d^2} = 0.025$ and 0.027 cc/L for wire and echo depths respectively.

Oxidation of the reversing bottom water samplers. During the first part of the cruise we repeatedly observed oxygen contents near the bottom, which were considerably lower than those obtained with the lowest ordinary Nansen water bottles of the serial observations. This made us doubt whether the metal parts of the inside of the reversing bottom water sampler, shown in Vol. I Ch. I, Pl. V Fig. 4, did not absorb oxygen. In that case the discrepancies observed would be due or partly due to oxidation of the water sampler, which absorbed oxygen from the sea water. It actually appeared from the examination carried out at our request by Dr. Liebert at den Helder (after the expedition) that a considerable oxidation took place in the reversing samplers, while with the Nansen bottles the oxidation was much less (11, p. 7 ff.).

On the other hand a complete analysis of our material shows it to be also possible that the sudden changes in the oxygen near the bottom may be real. As this cannot be ascertained with certainty, unfortunately, *we will give the arguments for and against as completely as possible.*

1. While still on board some research was made as to the effect of oxidation of the reversing bottom water samplers upon the oxygen content of the bottom samples. Subsequently to st. 193 an ordinary serial sampler was generally used as well as the reversing bottom water bottle, attached at a short distance below it. The serial bottle (B) was reversed by a messenger dropped by a bottom water sampler (M 42) on reversing as described by Hamaker (11, p. 8). In this way we obtained two water samples from the same level, the O_2-content of which was determined. The contents are found in Table 19.

TABLE 19. Comparison of the O_2-content of samples from the same level obtained simultaneously with different water bottles.

Station	O_2-content cc/L						Depth
	M 42	B_3	B_6	B_{11}	B_9	Δ	m
197	2.15	2.28				0.13	5100
200	2.18	2.27				0.09	1065
205	2.36		2.45			0.09	3903
209	2.43	2.53				0.10	4202
213	2.27	2.38				0.11	1102
224	2.42		2.48			0.06	1052
226	2.58		2.61			0.03	393
227	2.80		2.85			0.05	2934
229	2.48		2.56			0.08	5100
232	2.40		2.52			0.12	4563
236	2.33		2.40			0.07	3564
241	2.34			2.46		0.12	4796
242	2.37			2.43		0.06	3308
260	3.34				3.47	0.13	7797
261 *l*	3.31				3.48	0.17	9844
262	3.12				3.39	0.27	10035
264 [1]	3.26				3.37	0.11	±4200

Table 19 shows that the values obtained with the ordinary B-samplers were always higher than those from reversing bottom samplers, the mean difference is 0.11 cc/L, a value which agrees well with that estimated by Hamaker (11, p. 7) and based on the experiments of M. Knudsen (15). Consequently the content of the B-sampler was regarded as the right one, the more so as this content corresponded best with the results of the serial observations. Consequently the sample from

[1]) At st. 264 at 9148 m depth a temperature of 1°.61 C was determined; this shows that at this station the samplers had reversed at about 4200 m. According to the serial observations the O_2-content at this depth is 3.4 cc/L; the sampler B_9 gave 3.37 cc/L.

the M-bottle was no longer titrated after a time, so that the material for comparison was limited. When through the breaking of the sounding wire the last but one of the reversing bottom water samplers was lost a reversing thermometer frame, being lighter, was used for dropping the messenger and reversing the ordinary sampler hanging close below it.

The differences in Table 19 are rather irregular but if they are plotted against the depth, as in fig. 2, we see that the line drawn through the points shows an increase with the depth. As with the reversing bottom water bottles no samples were raised from depths of more than 6000 m the correction to be applied will not exceed 0.1 cc/L. Considering the uncertainty there is no reason for deducing one or more corrections from fig. 2 for depths less than 1500 m. *We shall therefore be satisfied with a correction of* +0.1 cc/L *in the case of samples obtained with a reversing bottom water bottle from depths between* 1500 *and* 6000 m.

The correction is certainly not entirely satisfactory; for comparison we have only at our disposal the observations with the M 42 bottle, while other M-bottles of the same type were used. Moreover the sudden changes vary very greatly and often were not observed at all.

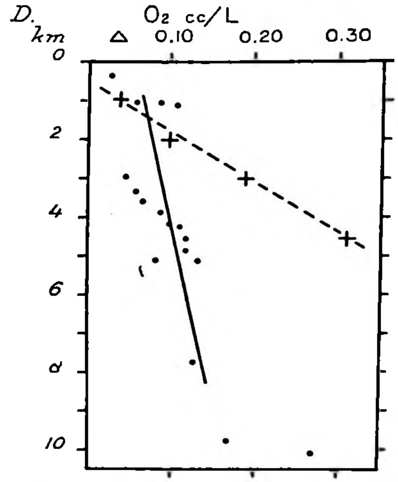


Fig. 2. Full drawn line: Differences (Δ) between the oxygen content of two bottom water samples obtained simultaneously at the same depth, one taken with a reversing bottom water sampler, the other with an ordinary serial water bottle. (Table 19).
Dotted line: Differences (Δ) between the mean bottom oxygen content for the water layers 500—1500, 1500—2500, 2500—3500 and 3500—5600 m and the mean values for the same layers determined from the hypothetical bottom oxygen contents which are in good agreement with the lowest serial observations. (Table 20).

To estimate the magnitude of the sudden changes, at all stations where an M-sampler had been used we examined which bottom O_2-content corresponded best with the serial observations. After this the differences, rounded off to 0.05 cc/L, were determined between these hypothetical values and the observed contents. The results showed that the same sampler in some cases yielded varying differences, while in many cases no discontinuity was observed. To examine whether the differences change with the depth of observation, they were arranged separately for depths of 500—1500, 1500—2500, 2500—3500 and 3500 to 5600 m omitting the great deviations observed at sts. 106, 108 and 168 as these occurred locally and are not supported by results obtained at neighbouring stations. The mean differences calculated for each layer and expressed in 10^{-2} cc/L, with the number of comparisons between brackets are found in Table 20.

TABLE 20. Differences between the mean bottom O_2-content observed with a reversing bottom water bottle and the mean bottom content which agrees well with the serial observations.

Depth	500—1500	1500—2500	2500—3500	3500—5600	m
Mean difference .	4 (38)	10 (24)	19 (19)	31 (10)	10^{-2} cc/L

These mean differences are plotted for the mean depth in fig. 2, the dotted line drawn through the crosses shows a more rapid increase with the depth than the full drawn line based on the data of Table 19. If the inclination of the latter is attributed to the fact that the water sample is the longer in contact with the inside of the water bottle the greater the depth, the course of the dotted line will show that there are other forces at work as well as absorption of oxygen by the water bottle to cause the O_2-content to decline near the bottom.

Table 21 gives in percentages the number of times that no deviation was found near the bottom, when using a reversing bottom water bottle.

TABLE 21. Number of times (percentage of number of observations) that no discontinuity in the vertical oxygen distribution was observed.

Depths	500—1500	1500—2500	2500—3500	3500—5600	m
No deviation . .	61%	38%	21%	20%	

2. There is some system in the distribution of the stations where important deviations in the bottom oxygen contents occur. If on a chart of the area of research the stations are marked where reversing bottom water bottles were used and which fulfil the following conditions:

a. depth more than 1000 m

b. deviations of 0.20 cc/L or more when no correction was applied,

it will be seen that the rapid changes in the O_2-content near the bottom take place at stations which are not scattered over the whole area, but lie near to each other in well-defined regions.

Thus, in the *Sulu sea* the discontinuity occurs all over the basin with the exception of the stations in the south. Nevertheless the magnitude of the deviation decreases gradually from north to south. In the *Celebes sea* there is an elliptical area in the south where there are rapid changes in the O_2-content to the north of the northern arm of the island of Celebes (Pl. I). The long axis of the ellipse runs parallel to the coast through sts. 49 and 53. In the *Sawoe sea* the rapid change occurs in a long and narrow area on the northern side of the basin and in the *Indian* Ocean a similar area is found with the axis through sts. 147 and 145 to near st. 131. The greatest change is found near the bottom at st. 145 and decreases gradually towards the north, east and south. In the *Timor trough* the rapid change is most conspicuous in the central deepest part of the trough. There is no certainty as to the discontinuity near the bottom of the *Aroe basin* as the observations at st. 100 were not considered reliable and those at st. 104 were carried out with an antiquated Sigsbee sampler. Here too we must allow for the possibility that the poverty in oxygen may be real in the deepest part of this basin.

This local occurrence of sudden changes in the O_2-content of 0.2 cc/L and more indicates a general cause, the most obvious being the effect of the sea floor upon the O_2-content by oxidation of organic debris when the ventilation of the water is less effective.

H. Wattenberg (16) states as follows:

„Der Vorgang der Zerzetzung und damit der Sauerstoffzehrung spielt sich demnach nur in „einer begrenzten oberen und mittleren Wasserschicht ab. Dass in den grössten Tiefen von etwa 2 km an „abwärts fast keine Zehrung mehr stattfindet und sich daher hier kaum noch oxydierbare organische „Reste befinden können, müssen wir auch aus dem über Tausende von Kilometern annährend konstanten „Sauerstoffgehalt des sich von Norden nach Süden bewegenden Nordatlantischen Tiefenwassers schliessen.

The author (17) apparently does not here refer to the bottom water. In Band VIII, 1. Teil, 1933, p. 173 we read:

„Die Sauerstoffarmut der bodennächsten Schichten ist also wie die erhöhte Alkalinität eine „Eigenschaft, die vom Boden aus sich den darüber befindlichen Schichten durch den turbulenten Aus- „tausch mitteilt.

From figures 14 and 16 in this „Meteor Report" it appears that the rapid O_2-decline occurs at bottom depths of 4000 to 5000 m at stations in the equatorial and subtropic areas. Further on the same page we read:

„Je langsamer der Bodenstrom ist, um so langsamer wird das Wasser erneuert, und um so „stärker wird also das Sauerstoffdefizit und die Erhöhung der Alkalinität steigen können. Umge- „kehrt kann man aus dem Sauerstoffdefizit und der Alkalinitätserhöhung (wie übrigens auch aus „dem pH) auf die Strömungsgeschwindigkeit schliessen ....". On p. 175 the increase in alcalinity and the decline in oxygen-content near the bottom is considered as *„ein normales Verhalten"*.

From the „Snellius" observations it appears that the rapid decline in O_2-content near the bottom is often accompanied by an equally rapid increase of pH. Data on this subject will be found in IV C of this chapter; for the Celebes sea (p. 46), Makassar strait (p. 48), the Sawoe sea (p. 55), the Flores sea (p. 58), the Kaoe bay (p. 61)[1]), the Indian Ocean (p. 62) and the Sulu sea (p. 66).

[1]) In this particular the Kaoe bay holds a special place.

It is remarkable, however, that the rapid changes in these two respects are particularly conspicuous in the regions where reversing bottom water samplers were used. After these instruments had been replaced by serial samplers deviations near the bottom from the normal vertical distribution were very seldom recorded. Nevertheless it should be mentioned that at the stations where the O_2-poor bottom water samples were taken from the bottom water bottles, the lowest *serial* bottle also more than once indicated a decline of the O_2-content. This is specially the case at st. 155 [1]) lying in the central part of the Sawoe sea [2]). The *serial* observations between 2980 m and 3180 m show a marked decrease of the oxygen content while the pH does not change. In accordance with the other stations of Table 31 the O_2-decrease near the bottom is still more important and is accompanied by an increase of pH. This increase need not be due to the solution of calcareous deposits from the sea floor only. It is questionable whether it is not caused by the reversing bottom water sampler absorbing carbon dioxide as well as oxygen.

In connection with this we will consider the simultaneous bottom observations carried out at st. 200 with a reversing bottom water sampler (M) and an ordinary serial sampler (B).

St. 200

D	O_2	pH	Bottle
1000	2.26	7.80	B
1065B	2.18	7.90	M
	2.27	7.80	B

If in this case the increase of pH was due to solution of lime from the bottom deposits, *both* bottom water samples should display this phenomenon whereas it is only the sample from the M-bottle that does so.

Experiments carried out after the conclusion of the expedition as well as the simultaneous observations near the bottom (Table 19, fig. 2) showed that oxygen was consumed from the bottom water by oxidation of the bottom water bottles. By applying the correction determined from fig. 2, p. 33 the rapid decrease of the oxygen content near the bottom observed at several stations was not eliminated.

The above mentioned results, further details of which are given in IV, C do not supply sufficient evidence for an explanation of the rapid changes observed in the O_2-content near the bottom. The results of the *complete* analysis of the chemical material and of the samples from the sea floor must be awaited [3]). Wattenberg (16, p. 49) mentions other causes for the consumption of O_2 in the deep water besides oxidation of organic matter contained in the deposits of the sea floor, but this brings us too much into bio-chemical territory. For the present we must be satisfied with attributing the phenomenon to insufficient ventilation owing to a slow movement of the bottom water.

---

[1]) p. 55, Table 31.
[2]) p. 54.
[3]) The geologist of the expedition, Dr. Ph. H. Kuenen, as the result of a preliminary research, makes the following statement „There does not appear to be any connection between the amount of organic matter contained in the deposits on the sea floor and the percentage of oxygen in the overlying water.

The bottom samples of which nitrogen as measure of organic matter had been determined, were divided into two groups; those containing 0.100 and more percent of nitrogen and those with less. The oxygen content of the bottom water sample and the lowest sample of the serial observations was averaged for each station. It was found that the water of the first group of deposits averaged 2.50 and over the second 2.48 cc O_2 per liter. This difference is negligeable, so that the absolute amount of organic matter in the ooze and of oxygen in the water are entirely independent factors.

The nitrogen percentages were also compared with the O_2-determinations obtained at stations where multiple bottom water samples had been taken. Again a negative result ensued. At station 66 a strong decrease of O_2 in the water was found towards the bottom, but the nitrogen of the deposit was 0.110, a value close to the average (the average is 0.100). At station 80 the O_2-decrease was slight and the nitrogen was low (0.085). At station 374 the nitrogen was low (0.060) and at station 330 it was high (0.290) but at neither was there a decrease of O_2 towards the bottom".

The above may be summarized as follows:

1. Considering the seasonal fluctuations and the changes from year to year in the O_2-content, the isolines on Pl. I are based on observations from depths of more than 600 m. The lines are drawn for the area limited by the depth contour of 1000 m. In Table 36, however, all results are included.
2. Over the whole area we found a standard error of 0.02 cc/L for the mean of the double titrations.
3. For the standard error in a free water layer due to internal waves (A) and to errors in the depth of observation (wire and echo depth, B) the following values were found.

TABLE 22. Standard error for the O_2-content in 10^{-2} cc/L.

	Depth in metres			
	400	500	600	800
A.	3.0	2.4	1.2	1.2
B (W.D.)	3.0	1.6	1.0	1.0
B (E.D.)	4.8	2.8	1.4	1.6

4. Considering the possibility of oxidation of the reversing bottom water samplers a correction of +0.1 cc/L was applied to various bottom observations from depths of more than 1500 m.
5. Considering the sources of error, the isolines on Pl. I are drawn with an interval of at least 0.1 cc/L.

B. Multiple bottom water observations carried out by means of wire soundings.

TABLE 23. Multiple bottom water observations.

Area	Station nr.	Depth m	Depth of Observation m	Temp. ° C	Salinity ‰	Oxygen cc/L	Water bottle
Sulu sea	66	4483	4392	—	—	1.42	S 35
			4422	—	34.44	1.49	S
			4452	—	—	1.14	S 34
Celebes sea	76	5544	5453?	—	—	1.25?	S 35
			5483?	—	34.53	0.78?	S
			5513?	—	—	1.71?	S 34
Batjan basin	80	4617	4526	—	—	2.69	S 4
			4556	—	34.61?	2.69	S 3
			4586	2.21	—	2.53+0.1	M 38
Aroe basin	104	3296	3205	3.94^5	34.65	2.15+0.1	M 38
			3235?	—	.65	—	S 3
			3265?	—	.63	2.04	S 4
Ind. Ocean	145	5722	5631?	1.29^5	—	3.99+0.1	M 38
			5661?	1.31^5	—	3.87+0.1	M 42
			5691?	—	—	2.66?	S 1
Sawoe sea	163	3296	3205	3.42^6	34.62	1.80+0.1	M 38
			3235	—	.63	1.80	S 1
			3265	—	—	—	M 42
Flores sea	180	5033	4940	—	34.56	2.03+0.1	M 40
			4970	—	.55	2.04	S 1
			5000	—	—	—	M 42

Area	Station nr.	Depth m	Depth of Observation m	Temp. °C	Salinity ‰	Oxygen cc/L	Water bottle
SW-Banda sea	202	3898	3805	3.13	34.60^{5}	2.39+0.1	M 42
			3835	—	$.60^{5}$	2.39	B 4
			3865	—	—	—	B 6
SW-Banda sea	205	3936	3843	3.15^{5}	34.60^{5}	2.37+0.1	M 42
			3873	3.13	$.60^{5}$	2.45	B 4
			3903	—	$.60^{5}$?	2.36?	B 6
NW-Banda sea	209	4225	4142	3.12	34.60^{5}	2.53	B 6
			4172	3.13	$.60^{5}$	2.43	B 8
			4202	3.13	.61	2.53	B 12
NW-Banda sea	212	4968	4898	3.23^{5}	34.61	2.46	B 11
			4928	3.24^{5}	.63	2.45	B 14
			4958	3.21?	$.60^{5}$	2.46	B 10
Manipa strait	253	4024	3931	3.21	34.60	2.41	M 17
			3961	3.22	.60	2.44	M 16
			3991	3.23^{5}	$.60^{5}$	2.42	B 7
Kaoe bay	278	491	401	—	34.46	0.00	M 18
			431	—	.45	0.00	M 17
			461	—	.48	0.00	M 16
Kaoe bay	280	357	267	28.31	34.43	0.22	M 21
			297	—	.44	0.24	M 18
			327	—	.44	—	B 5
SW-Celebes sea . . .	309 *l*	5108	5015	3.81?	34.60^{5}	2.08	B 10
			5045	3.86	$.60^{5}$	2.05	B 11
			5075	3.86	.60	2.08	B 12
Ceram sea . . . . . . (Boeroe basin)	330	4450	4360	3.09^{5}	34.61	2.55	B 1
			4390	3.10^{5}	.61	2.54	B 2
			4420	3.11	.61	2.55	B 3
NW-Banda sea	331	5026	4476	3.18	34.63	2.48	B 7
			4726	3.21^{5}	.63	2.50	B 8
			4976	3.25	.62	2.50	B 9
Biaro strait	341	1305	1205	3.87^{5}	34.58	2.37	M
			1285	3.81^{5}	.56	2.37	M
Molukken sea	347	3061	2511	1.86	34.68	3.03	M 8
			2761	1.85	.67	3.01	M 9
			3011	1.88^{5}	.66	3.04	M 10
„Snellius" ridge . . .	348 *l*	2198	1973	2.22^{5}	34.65	—	M 19
			2073	2.06	.64	—	M 20
			2173	1.94	.66	—	M 21
Weber deep	362	7326	7233	—	34.61	2.36	B 10
			7263	3.63^{5}	.63	2.35	B 11
			7293	3.63^{5}	.63	2.38	B 12
Between Weber deep and Wetar basin . .	374	2509	1759	3.36^{5}	34.61	2.37	B 9
			2259	3.17	$.60^{5}$	2.43	B 10
			2459	3.17	.62	2.40	B 11

For examining the discontinuity in the oxygen content of the bottom water serial observations were made with the wire soundings at a short distance from the sea floor. When the Lucas sounding apparatus was used with a piano wire of 1 mm diameter and a Sigsbee tube or the ordinary sounding tube, a portion of the serial cable of 4 mm diameter and 60 m length was introduced between the stray-line of hemp and the piano wire, as detailed on p. 56 of Vol. I. The water bottles were attached to the serial cable at the desired intervals.

To guard against breakage of the fine wire as much as possible we used at first three light Sigsbee samplers, subsequently we combined two Sigsbee samplers with a reversing bottom water sampler. Later one of the Sigsbee samplers was replaced by a reversing bottom water bottle, so that more temperature observations were obtained. But considering the possibility of oxidation of the inside of the reversing bottom water bottles we finally resorted to ordinary serial samplers. These were reversed by a messenger released when reeling in by a reversing bottom water sampler or reversing thermometer frame [1]) hanging above the serial bottles.

Several times a sounding tube of 4 m length (18) weighing between 100 and 160 kg or, when no bottom sample needed to be brought up, a weight of about 60 kg were used. In both these cases the wire was paid out by the serial winch and a serial cable of 4 mm. The bottles were attached to the wire at the desired intervals with a reversing frame above to reverse the serial samplers when the messenger was not released from the sounding platform.

When working with the reversing thermometer frame above the samplers there is a risk of the instrument not functioning properly so that none of the serial bottles reverse at the right time; in the other case there is a danger of the messenger while slipping down the cable being caught on some object that has got entangled in the wire (e.g. jelly fish) or on a loose strand of the wire, causing the same negative result. Moreover in the latter method the sounding tube must remain on the sea floor during the descent of the messenger until the lowest bottle is reversed. To meet the last difficulty and also to save time, we released the messenger from the sounding platform before the sounding tube had reached the bottom, taking into account the time of adaption of the thermometers. It is important to be sure that in the latter case the serial winch is in proper working order so that no hitch may occur while paying out.

The distance from the bottom when using three bottles was usually about 30, 60 and 90 m. During the last part of the research observations were also made at greater distances, but the results of these are not included in Table 23, when the distance of the lowest sampler from the one above it was more than 250 m.

The water samples were procured with reversing water samplers (M. 38, M. 40 and M. 42), Sigsbee bottles (S) and ordinary Nansen samplers (B and M). In the Table the *observed* values are given, so that temperature and salinity in some cases may show an insignificant deviation from the values in the complete Tables of serial and bottom observations which will be included in the following Part of Vol. II. In this case the last mentioned values are derived from the T.D. and S.D. curves. A correction of +0.1 cc/L [2]) was applied to the oxygen determinations made with the M 42-, M 40- and M 38-samplers.

Before proceeding to a discussion of the multiple observations we append a more particular account of the position of the stations where these observations were made.

Station 66 lies in the Sulu basin in the southwestern arm of the deeper furrow which runs parallel to the ridge of the Sulu Archipelago on the east side of the basin.

Station 76 lies in a similar depression running parallel to the northern arm of Celebes in the southern part of the Celebes basin.

Station 80 lies in the centre of the Batjan basin.

Station 104 is found in the centre of the Aroe basin between the Kai and Aroe groups.

Station 145 lies to the south of the island of Soemba in the most eastern region of the Java trough.

Station 163 lies in the centre of the eastern part of the Sawoe basin.

Station 180 is found in the centre of the elongated central and deepest part running from west to east in the Flores basin.

---

[1]) Vol. II Part 1. p. 8.
[2]) p. 33.

Stations 202 and 205 are situated in the western area of the Southern Banda basin south of the Toekangbesi islands.

Station 209 lies in the southern part of the Northern Banda basin; *station 212* in the centre of this area north of the ridge stretching from the island of Wowoni to the east.

Station 253 is found in the centre of the Manipa strait in the northern deepest portion of the Manipa basin.

Station 309I lies at the extreme point of the westward arm of the central deepest part of the Celebes basin to the north of Makassar strait.

Station 330 lies in the centre of the eastern portion of the Boeroe basin.

Station 331 lies about 10 sm west of station 212 (see above).

Station 341 lies at the south side of the threshold in Biaro strait which connects the Celebes and Molukken seas.

Station 347 lies in the northern part of the Ternate trough (eastern marginal depression of the Molukken sea).

Station 348I is situated to the north of the island of Morotai on the threshold which separates the Pacific Ocean from the Molukken sea („Snellius"-ridge).

Station 362 lies in the centre of the Weber deep.

Station 374 is found in the passage between the Weber deep and the Wetar basin to the west of the island of Kisar.

Northern area of the Celebes sea. The first multiple bottom observations were on the observation programme of st. 57 in the northern area of the Celebes sea. An ordinary sounding tube was paid out on the piano wire by the Lucas sounding machine with a reversing thermometer frame and three Sigsbee water bottles. The paying out ran normally; but when 100 m had been reeled in the piano wire broke at a joint.

Sulu sea. In consideration of the important decline in the oxygen content near the bottom in the Sulu sea the bottom observations at st. 57 were repeated at st. 66 in the southern area of the Sulu sea. To make the tension in the wire when reeling in as small as possible we omitted the reversing thermometer frame so that no temperature data were obtained. Moreover we replaced the expensive sounding tube by a Sigsbee tube the 25 kg weight of which remained on the sea floor, when the core tube was hauled up. The Sigsbee samplers were attached at 31, 61 and 91 m above the lead. The lowest serial sampler hanging at 4400 m [1]) yielded an O_2-content of 1.66 cc/L. Compared with this value the three bottom observations indicate a rapid decline of the O_2-content, especially from 61 to 31 m above the floor.

Celebes sea. The observations in the Sulu sea were repeated at st. 76 in the southern area of the Celebes sea in the same manner and with the same instruments. At the moment when the Sigsbee lead would be near the bottom we steamed ahead which is probably the reason why the Lucas sounding machine did not stop at the moment when the lead reached the sea floor. The ballast weight of 25 kg was released all the same and the Sigsbee tube yielded a bottom sample. After reeling in the measuring wheel stood at minus 207 m; presumably after the bottom had been reached the wire continued to run out, without the measuring wheel registering it. Thus the depth from which the water was brought up is uncertain, and it is not impossible that the distance from the bottom was less than had been intended. It is even possible that the water bottle S 34 which was slightly damaged was dragged along the bottom. This instrument proved to be leaking when it was detached which explains the high O_2-content of 1.77 cc/L. Considering the uncertainty of the depth of observation the bottom observations at this station were not made use of in drawing Pl. I. In any case the decrease near the bottom seems to be considerable as the O_2-content observed with the *serial* observations between the levels of 2940 and 5140 m was constant at 2.07 cc/L. The salinity of the middle sampler only was determined, which corresponds to the serial observations at 2940, 3940 and 5140 m depth.

Southern area of the Molukken sea. At st. 80 in the Batjan basin a Sigsbee tube was paid out by the Lucas sounding machine, loaded with a 35 kg weight. This weight in future, with a single

[1]) The ship, after the wire sounding, drifted to a greater depth in SSE-ly direction.

exception (see p. 42), was not left on the sea floor in the hopes that it would thus yield a longer bottom sample. The reversing bottom water sampler M 38 and the two Sigsbee bottles hung at 31, 61 and 91 m respectively above the sea floor.

The two salinity titrations of the sample from the S 3-bottle yielded the same value, viz. 34.61‰. Probably these titrations were not correct as the lowest serial observations show a constant salinity of 34.67‰ in the deep layers. The two O_2-determinations, 91 and 61 m above the sea floor correspond well to the content determined from the water sample in the lowest bottle of the *serial* observations at a depth of 4170 m (2.63 cc).

Aroe basin. The same method of procedure was applied at st. 104. According to the observation register the following values were obtained.

Depth of Observ.	Above the bottom	O_2	pH	Sampler
3205 m	91 m	2.15 + 0.1	7.95	M. 38
3235 m	61 m	1.85	8.15	S. 3
3265 m	31 m	2.04	7.96	S. 4

The lowest *serial* observation at 2990 m yielded:

$O_2 = 2.25 \qquad pH = 7.83$

The low O_2-content at 3235 m lying between the much higher values above and below it, cannot be correct. The reason of it is not a leakage in the Sigsbee sampler, as such a low O_2-content is not found in a single niveau. Unfortunately the original O_2-notations are not available so that we cannot trace whether the water samples of the two Sigsbee samplers were exchanged. If this were the case these observations would confirm the rapid diminution noticed at st. 100 in the Aroe basin [1]). The high pH of S 3 also indicates that this sample was probably raised from a depth of 3265 m. Considering this uncertainty, the content at 3205 m was used in drawing Pl. I.

Indian Ocean. At st. 145 two reversing water samplers with a Sigsbee bottle below them were paid out by the Lucas sounding machine to 91, 61 and 31 m above the sea floor. At the bottom of the wire a Sigsbee lead loaded with 35 kg was attached. The lowest bottle was filled with muddy water and had obviously been in contact with the sea floor, consequently in compiling Pl. I a content of 3.97 cc at 5661 m was used. All observation depths near the bottom are uncertain it must be remembered.

The salinity titrations are incorrect, they deviate considerably from the value 34.72‰ which was obtained from the lowest serial sampler. The O_2-content from the lowest bottom sampler shows a rapid decline, which cannot well be accounted for by leakage. The samples from the other bottles also indicate a decline of the O_2-content with the depth. The lowest sampler of the *serial* observations gave 4.27 cc/L at 5480 m.

Sawoe sea. At st. 163 an ordinary sounding tube was paid out with three samplers above it at a distance of 31, 61 and 91 m. As the samplers of the *serial* observations yielded an O_2-content of 2.15 cc between 2230 and 3180 m, the O_2-contents from the bottom observations showed at 3205 m and 3235 m a rapid decline. As the lowest bottom sampler came up empty this decline could not be confirmed by an O_2-determination at a still shorter distance from the bottom.

Flores sea. As at st. 163 at st. 180 three observations were made near the sea floor, in which two reversing bottom samplers and one Sigsbee sampler above the ordinary sounding tube were lowered by the Lucas sounding machine. Only the thermometer of M 42 yielded a bottom temperature of $3^{\circ}.64^{6}$, which seems to be too high. Probably this sampler reversed at 1450 m instead of 5000 m. The O_2-content at 63 m above the bottom shows a decline compared to that at the level of 4940 m if a correction of +0.1 cc is applied to the content of the sample from M 40. The lowest *serial* observation yielded an O_2-content of 2.16 cc at 5000 m. The water in the sounding tube showed a salinity of 34.59‰.

[1]) p. 65.

SW-Banda sea. In this region at st. 202 use was made of two ordinary serial samplers for the first time reversed by a messenger released by the reversing of the M 42-sampler hanging above it. The thermometer of B 4 showed an after-flow of the mercury; from the readings of the thermometer attached to the lowest sampler, B 6, it appeared that the instrument had reversed at about 30 m depth. It was not till the sampler B 4 was detached that its messenger was released and struck B 6. After the application of a correction of +0.1 cc to the O_2-determination of M 42 a decline of the O_2-content with the depth became apparent. It is doubtful whether in M 42 oxidation of the inside actually took place, as the *serial* samplers from 2485 to 3735 m yielded an O_2-content of 2.37 to 2.40 cc, a content which corresponds to the *uncorrected* value from sampler M 42. For raising the bottom sample, a Sigsbee tube loaded with a 25 kg weight was used.

At about 75 sm east of st. 202 at st. 205 the same bottom observations were carried out with the same samplers and an ordinary sounding tube of 32 kg. The thermometer of B 6 at 33 m above the bottom gave a temperature of 3°.89 which is too high. If this was due to a defect of the thermometer and the sampler B 6 had reversed at the proper time it can be said that the water samples of B 4 and B 6 show a decline of the O_2-content with the depth. But there is no certainty regarding this as the salinity and O_2-content of B 6 also fits in with the niveau of 1300 m, where a temperature of 3°.89 C prevails. The lowest *serial* sampler gave an O_2-content of 2.43 cc at 3520 m depth.

NW-Banda sea. So far the success was not great as we several times had trouble with the reversing of the water bottles. On this account at st. 209 in the north-western region of the Banda sea we made use of a weight of 60 kg which was paid out on the 4 mm wire by the serial winch. At the bottom end of the serial cable a stray-line of hemp of about 30 m length was fastened. A weight of 10 kg, attached above the stray-line to the serial cable prevented the cable from kinking after the 60 kg weight struck the bottom.

At 23, 53 and 83 m above the weight three ordinary serial samplers were attached. By reading the tension meter fixed to the wire the moment at which the weight lay upon the bottom could be accurately determined and constantly controled. The samplers were reversed in the usual way viz. by the release of a messenger from the sounding platform. The deviation of the O_2-content at 4172 m compared to that above and below it is not normal; according to the *serial* observations the content at 3480 m was 2.51 cc/L.

In the same area at st. 212 three observations were made in the same manner at 10, 40 and 70 m above the sea floor. The temperature of 3°.21 at 4958 was determined by two thermometers, which gave the same value. It is possible, therefore, that the sampler B 10 reversed a little too high, at st. 311 (see below) in the immediate neighbourhood, six months later we determined a temperature of 3°.25 at 4976 m. This value agrees with the other bottom temperatures at st. 212. The O_2-contents correspond very well, not only mutually but also with the observations of st. 331 [1]). The lowest *serial* sampler gave a content of 2.37 at 4780 m.

Manipa basin. At st. 253 in the Manipa basin lying between the islands of Ceram and Boeroe, an ordinary sounding tube of 32 kg was paid out. On the serial cable attached between the stray-line and the piano wire three ordinary serial samplers were fastened, 33, 63 and 93 m above the sounding tube. The bottles were reversed by a messenger released during reeling in by a reversing thermometer frame hanging above them.

The observations were very satisfactory; there are no signs of a decline of the O_2-content near the bottom in this small basin closed from the Banda sea by a thresbold at 3100 m depth. The lowest *serial* sampler gave an O_2-content of 2.43 cc at a depth of 3790 m.

Pacific Ocean. The three bottom observations in the Pacific Ocean at st. 271 at a depth of 7846 m unfortunately yielded no results as the bottles did not reverse at the right time. The method of working was the same as at st. 253 in the Manipa basin but it seems that the reversing thermometer frame did not work properly.

Kaoe bay. In the Kaoe bay (island of Halmahera) which is separated from the Pacific Ocean by a threshold at 40 to 50 m depth, at st. 278 three observations were carried out at 30, 60 and 90 m above the bottom with ordinary water samplers. The bottles were attached to the serial cable of 4 mm by which the heavy sounding tube of 120 kg was lowered. The bottles were reversed by a messenger. No oxygen was found in the samples, but we observed traces of hydrogen sulphide viz.

[1]) p. 42.

0.09, 0.09 and 0.16 cc/L at 401, 431 and 461 m respectively. No temperature observations were made with this sounding. According to the preceding serial observations and the ordinary wire sounding the temperature was 28°.29⁵ and 28°.32 at 400 and 450 m respectively.

A second set of observation was made in this bay at st. 280 with the heavy sounding tube (weight 100 kg). Three ordinary water samplers were fixed at 30, 60 and 90 m above the bottom. The O_2-content of samplers M 21 and M 18 differ very little, while a decline with the depth was to be expected. According to the preceding serial observations and the ordinary wire sounding the O_2-content on the spot was at 250 m 0.31 cc and at 355 m 0.14 cc. The temperature at 355 m was 28°.32. For further particulars we refer to p. 60.

SW-Celebes sea. As there was a troublesome swell at st. 309*l* no heavy sounding tube was used but the ordinary one of 32 kg which was paid out with a reversing thermometer frame and three ordinary serial samplers at a distance of 33, 63 and 93 m from the bottom below it. The O_2-contents differ very little, serial observations were not carried out at this station so that no comparison is possible. The temperature at 5015 m deviating much from the two other bottom observations is probably erroneous.

W-Ceram–sea. (Boeroe basin). At st. 330 again three observations were carried out, and now with the heavy sounding tube which was loaded up to 140 kg. The observations at 30, 60 and 90 m above the bottom agreed well. The two lowest *serial* observations yielded for the O_2-content 2.55 cc/L both at 3475 and 3975 m. The samplers were reversed by a messenger sent down from the sounding platform.

NW-Banda sea. The same method of procedure was followed at st. 331 in the NW-region of the Banda sea, but now the ordinary serial samplers hung 550, 300 and 50 m above the bottom. The observations do not indicate a decline in the O_2-content near the bottom any more than at st. 212 in the immediate vicinity (see above).

Biaro strait. In this strait, lying at the NE-point of Celebes at st. 341 two observations were carried out at 100 and 20 m above the sea floor. The two ordinary serial samplers were attached to the serial cable on which a weight of 60 kg was lowered to the bottom. The samplers were reversed in the usual way by a messenger. No decline of the O_2-content was recorded. The *serial* observations at 990 m depth produced an O_2-content of 2.29 cc.

Molukken sea. In the eastern area of the Molukken sea at st. 347 we again made use of the large sounding tube of 140 kg. The ordinary serial samplers were reversed by a messenger at 550, 300 and 50 m above the bottom. The observations are well in agreement, the minimum temperature *in situ* of 1°.84⁵ at this station lies at 2600 m. The lowest *serial* observation yielded an O_2-content of 2.97 cc at 2485 m; the content increased gradually from 990 m with the depth.

„Snellius"-ridge. On the threshold that divides the Pacific Ocean from the Molukken sea, (the „Snellius"-ridge) at st. 348*l* a heavy weight was once more lowered. Three ordinary serial samplers were reversed by a messenger at 225, 125 and 25 m above the sea floor. There are no O_2-observations, the salinity observations agree well.

Weber deep. At st. 362 in the Weber deep a Sigsbee tube loaded with a weight of 46 kg was lowered by the Lucas sounding apparatus. With a view to the great depth in this particular case the weight remained below when reeling in the piano wire. At a distance of 93, 63 and 33 m above the floor three ordinary serial samplers were reversed by a reversing thermometer frame hanging above them. The three O_2-values differ very little; according to the *serial* observations the O_2-content at 6000 and 7000 m was 2.38 cc.

Between Weber deep and the Wetar basin. In the region between Weber deep and the Wetar basin the large sounding tube of 160 kg was paid out for the last time at st. 374. By means of a messenger three ordinary serial samplers were reversed at 750, 250 and 50 m above the sea floor. The minimum temperature *in situ* of 3°.16 was determined at 2350 m. The three O_2-values show only small differences.

If the above results are summarised we see that the observations at st. 205 and those following do not indicate any decline of the O_2-content near the bottom with the exception of the Kaoe bay which takes a peculiar place here. For stations 163, 180 and 202 this in only the case if a correction of +0.1 cc/L is applied to the observations with the reversing bottom water sampler. The bottom

O_2-contents observed at st. 163 deviate considerably from those obtained with the lowest *serial* water samplers. This is also the case at the remaining stations with the exception of st. 80.

All the bottom observations at st. 66 and 76 and some of those at stations 104, 145 and 163 were carried out with the antiquated Sigsbee samplers, moreover the bottles at stations 76 and 145 were filled with water from very near the bottom so that we are not certain of the level from which the samples were drawn. However, this does not prevent the results, both mutually and in relation to the lowest *serial* observations, from indicating a rapid decline of the O_2-content with the decrease of the distance to the bottom so that we can regard this decrease at the stations mentioned as being real.

C. Distribution of oxygen in the bottom water. — The ventilation of the bottom water due to vertical convection will be only slight in tropical areas, owing to the small changes in surface temperature. In oceans which lie in free connection with the polar areas this ventilation will take place in a meridional sense by the inflowing of bottom water rich in oxygen from the north or the south.

In the tropical inland seas separated from the ocean by thresholds the deep water will be shut off from the atmosphere by the layer of water above it. K. Münster Strøm (19) says in connection with this: „*From a hydrographical point of view there can hardly be any doubt that with a more* „*or less universally tropical, or at least equalized climate, or with barriers, which may very well* „*have been mainly submarine, between equatorial and polar seas, the oceans and great seas might* „*become insufficiently ventilated in the deep.*"

In the basins and troughs of the Archipelago the oxygen consumed in the bottom water will be *chiefly* [1]) compensated by the supply of oxygen from the water which flows over the deepest threshold and replaces the less heavy bottom water. Thus the threshold current takes over the part played by the water transport from higher latitudes in renewing the depth water in the great oceans.

In the course of time in the bottom layers a condition will always be reached in which the renewal and consumption of oxygen will compensate one another. But the oxygen content of the bottom water will in general be higher in proportion as the supply of oxygen is greater. This again is dependent upon the velocity with which the water flows over the deepest threshold, the oxygen content of the threshold current and upon the size of the threshold profile in proportion to the extent of the area that is to be ventilated.

Other circumstances being equal the oxygen content near the bottom will be locally small in the basin where the bottom current is feeble and vice versa, we may *in general* deduce a slight movement of the bottom water from a low oxygen content in a part of the basin.

If the *deepest* threshold current does not follow the bottom because in the basin it comes into equilibrium in higher water layers, the supply of oxygen to the bottom water will depend upon the stability of the deep water. In the partially enclosed tropical basins owing to the feeble vertical convection the renewal of the bottom water can only take place slowly and the equilibrium between supply and consumption can be reached only at a lower O_2-content. The effect of lighter water flowing in over *shallower* thresholds will here play only a subordinate part.

Our observations will show in how far the distribution of oxygen confirms and amplifies the conclusions — resting principally upon the distribution of the potential temperature — concerning the movement of the bottom water in the area of research. Moreover a local decrease of the oxygen content in a particular area will reveal a less complete renewal of the bottom water and indicate a feebler water movement, assuming that the amount of organic substance to be oxidised is equally distributed.

In consideration of the sources of error dealt with above [2]), for the construction of Pl. I we have only used those values from table 36 of which the depth of observation was 600 m or more, with the exception of the bottom observations from stations 76, 100, 118 and 168. The isolines are only drawn to a depth of 1000 m and with an interval of at least 0.1 cc/L. As a knowledge of the oxygen content is not of importance to the physical oceanographer only, in Table 36 we have included all observations.

The depth line of 1000 m is taken from the depth chart, a few details being omitted to make

[1]) We left out of consideration the vertical exchange.
[2]) p. 25.

the representation more distinct. Such details have here little significance as the object is to give a general representation of the distribution of the oxygen content in the bottom water of the various basins and to bring out the mutual connections clearly.

In connection with Pl. I we shall treat the oxygen distribution in the bottom and deep water and doing so, consider the inland seas successively according to the course of the bottom water as this has been deduced in Vol. II Part 2 Ch. II and diagrammatically represented on Pl. IV of that chapter. For the names of basins, straits, islands, etc. we refer to fig. 3, the depth chart appended to the above chapter and the route chart in Vol. I.

a. The influence of the Pacific water.

The Pacific Ocean. In the Pacific Ocean the bottom observations from the deep stations in the Mindanao trough show an oxygen content of 3.4 to 3.5 cc/L. This content decreases rapidly towards the west near Mindanao, the Talaud islands, the ,,Snellius" ridge and the island of Morotai, while in the southern part of the trough the decline is somewhat more gradual in the direction of Halmahera and the entrance to the Halmahera sea.

We shall now follow the course of the bottom water through the three entrances which connect the Pacific with the inland seas of the Archipelago. There are:

1. *The Straits between Mindanao and the Talaud islands.*

Through these straits the deep water is successively renewed in the Sangihe trough, the Celebes sea and the Makassar strait.

Sangihe trough. On p. 25 of Vol. I Part 2 Ch. II it was noted that the renewal of the bottom water took place by a direct supply from the Ocean and not indirectly around the central ridge of the Molukken sea. Fig. 4 shows [1]) that the ocean water flows over the threshold with an oxygen content of fully 2.7 cc/L at 2050 m so that at station 296 in the trough a content of 2.73 cc/L was found near the bottom. In the deep water an increase of the O_2-content was recorded; the pH varies between 7.81 and 7.80 from 1000 m to the bottom.

TABLE 24. Oxygen content and hydrogen-ion concentration in the deep layers of the Sangihe trough. St. 296.

Depth	O_2	pH
2050	2.55	7.81
2550	2.63	7.80
2800	2.63	7.81
3289B	2.73	7.80

We here give the hydrogen-ion concentration at the same time, because, as stated above at some stations a great change in the bottom O_2-content is accompanied by sudden changes in the pH.

Celebes-sea. The supply of comparatively oxygen-rich water from the Pacific is checked to the west by the Sangihe ridge which forms the connection between the islands of Celebes and Mindanao, fig. 4. To the south of Mindanao there is a threshold on this ridge at a depth of 1400 m. From the intermediate oxygen minimum of the Sangihe trough an oxygen-poor current of only small vertical measurement reaches just over this threshold with a content of about 2.15 cc.

Above the threshold the O_2 slowly increases and according to fig. 4 from there a tongue of the isoline of 2.2 cc/L reaches to greater depths in the Celebes sea, so that at st. 301 between 2500 and 3700 m more than 2.2 cc was found and the bottom water at st. 297 yielded 2.2 cc/L. As the depth increases the O_2-content gradually diminishes, so that at st. 301 the bottom amount reached a value of 2.14 cc.

Although the bottom observations in the Celebes sea consist of the corrected observations made

[1]) For the positions of the profiles see fig. 3.

Fig. 3. Chart showing the positions of the vertical sections.

with the reversing bottom water sampler and observations made with the serial water sampler a year later, it may be concluded from the course of the isolines on Pl. I that the bottom water from the above station 301 moves to the west, so that at st. 305 at the extreme western part 2.11 cc/L was still found, while the wire sounding at st. 309 *l* north of the entrance to the Makassar strait gave 2.08 cc near the bottom.

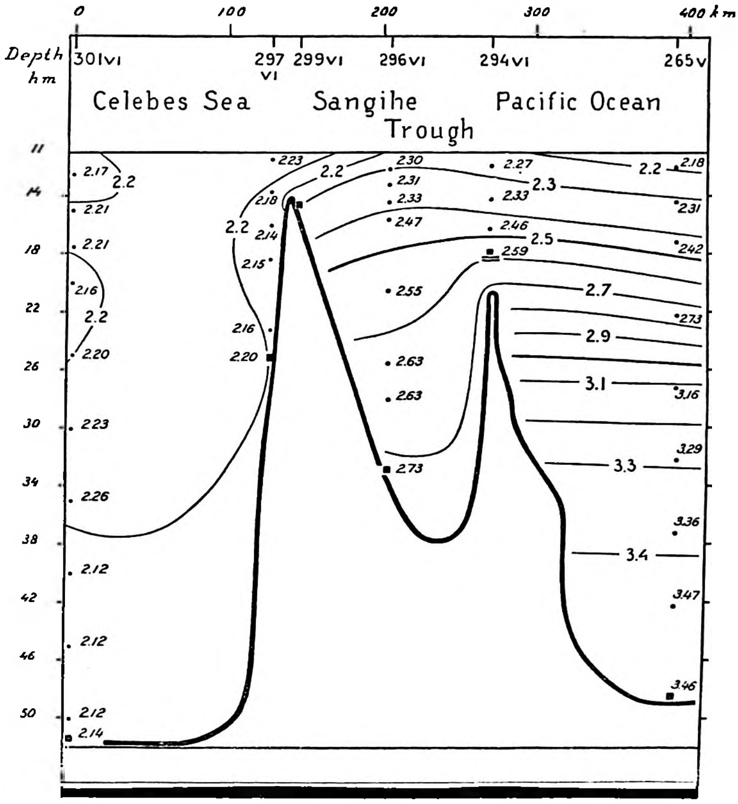


Fig. 4. The distribution of oxygen content along a vertical section across the passages south of Mindanao leading from the Pacific Ocean to the Celebes sea [1]).

To the north and south of this oxygen-rich bottom water the content declines very considerably especially towards the south where the poverty of oxygen in the bottom water is very evident. The rapid decrease near the bottom suggests that the renewal of the water here is very inadequate. On the other hand the discontinuity in the pH is here very striking, fig. 5, sts. 49 and 53.

In the deep water coming from the Sangihe trough and enclosed by the isoline of 2.1 cc/L, in the transition area and in the oxygen-poor region in the southern part of the Celebes sea we found successively the values of Table 25.

---

[1]) In this section and those following the true-scale bottom contour is shown at the foot of the diagram.

TABLE 25. Oxygen content and hydrogen-ion concentration in the deep layers of the Celebes sea.

Water transport from the Sangihe trough:					
St. 301			St. 303		
D	O_2	pH	D	O_2	pH
3500	2.26	7.81	2490	2.23	7.78
4000	2.12	7.80	2990	2.22	7.79
4500	2.12	7.81	3490	2.17	7.78
5000	2.12	7.81	3990	2.19	7.79
5138B	2.14	7.78	4386B	2.10	7.78

Transition area:			Centre of oxygen-poor area:					
St. 52			St. 49			St. 53		
D	O_2	pH	D	O_2	pH	D	O_2	pH
3000	2.10	7.84	1750	2.15	7.82	3500	2.01	7.83
3500	2.10	7.83	2000	2.15	7.80	4000	2.07	7.84
4000	2.05	7.84	2500	2.12	7.81	4500	1.98	7.84
4500	2.02	7.85	2750	2.06	7.82	4800	2.01	7.83
4986B	1.98	7.88	2979B	*1.61*	*8.17*	4973B	*1.62*	*8.13*

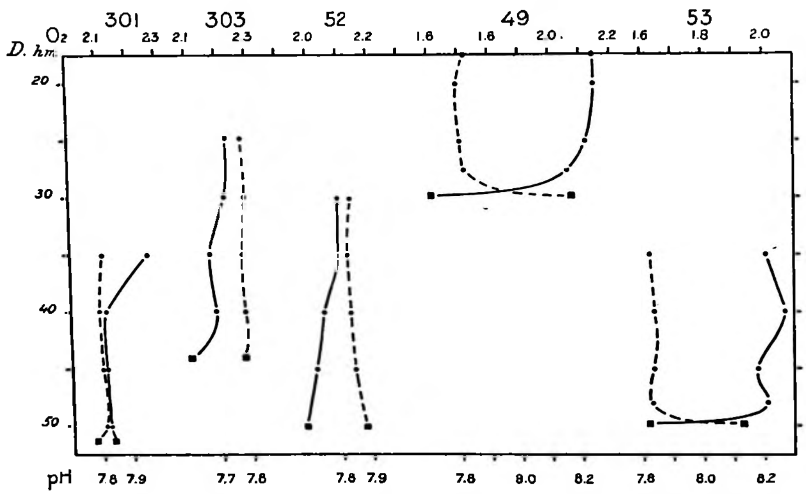


Fig. 5. Celebes sea. Oxygen-depth and pH-depth curves at successive stations between the entrance in the north-east and the oxygen-poor area in the south. The dotted lines represent the pH-curves. Bottom observations indicated by ■.

The bottom observations at stations 301 and 303 were made with an ordinary serial water sampler; those at stations 52, 49 and 53 with a reversing bottom water sampler. A correction of +0.1 cc/L was therefore applied to the latter.

The rapid decrease of the oxygen content near the bottom might be ascribed to oxidation of

the inner side of the reversing bottom water sampler, but in that case it would be a strange coincidence that this peculiar phenomenon should principally appear *in the south* of the Celebes sea. Moreover st. 52 does not show the discontinuity, while according to the original notes the bottom observations at stations 52, 49 and 53 were carried out with the same reversing bottom water sampler. The bottom observations with the serial water sampler at stations 301 and 303 also show a decrease near the bottom, although to a considerably modified degree.

Fig. 6 shows the diminution of the oxygen content in the deep water in proportion as we penetrate from the Sangihe trough (A) to the oxygen-poor area in the south of the Celebes sea. The horizontal dotted line, top right of the figure, indicates the position of the threshold which separates the Sangihe trough from the Celebes sea.

In the latter basin the bottom O_2-content gradually diminishes from B to E. From the curves it may be seen that the initial increase with the depth changes into decrease at E (st. 52). The sudden access at 5000 m of curve C (st. 301) is probably not real. In the southern area F shows a very rapid decrease near the sea floor, but the water sample from the lowest *serial* sampler showed also a decrease of 0.06 cc from 2500 to 2750 m.

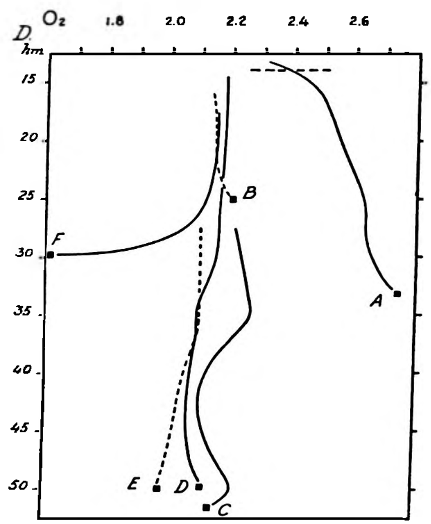


Fig. 6. Gradual change of the oxygen-depth curves from the Sangihe trough, A st. 296, to the oxygen-poor southern part of the Celebes sea. B. St. 297, C st. 301, D mean of stations 56 and 302. E st. 52 and F st. 49.

Makassar strait. From the Celebes sea the water enters the Makassar strait over an almost imperceptable threshold at 2300 m. The bottom here rises in a gentle curve towards the south.

If a vertical oxygen profile is drawn [1]) from north of the northern entrance passing through stations 43, 42, 41 (310), 39 (311), 312, 35, 33 and 31, to the south of the strait near Makassar itself, it appears that the deep water on the western side of the Celebes sea, with an O_2-content of 2.16 cc/L at st. 43, draws to the south, while remaining on the west side of the Strait. The observations at st. 39*a* in the year 1929 show that the effect of the depth transport could be felt as far as this station with a content of 2.13 cc near the bottom [2]). On this basis and by using the corrected bottom observations the isoline for 2.00 cc/L was carried on Pl. I to about 2° S. lat. and a separate area drawn for more than 2.1 cc.

According to the longitudinal section along stations 37, 38, 39, 39*a* and 40 [3]) the better ventilated depth water penetrates beneath the oxygen-poor water from the southern part of the Strait. In the latter area the oxygen content not only of the bottom water but also that of the layer above it gradually decreases towards the south.

In the Makassar strait, as well as in the southern area of the Celebes sea, sudden changes were observed in the oxygen content near the bottom at a few stations. All bottom water observations were carried out with reversing bottom water samplers, so that for depths of more than 1500 m a correction of +0.1 cc/L was applied. Table 26.

St. 30 lies in the extreme south-western part of the Strait at a small distance from the depth line of 200 m which encloses the reefs lying south of the station. A bad ventilation of the bottom water is thus very possible here. Nevertheless a decrease of 0.33 cc/L over a vertical distance of 240 m is very considerable, as is the leap in the pH.

---

[1]) Not given here.
[2]) This was not shown by the observations at st. 311 which were made a year later in the immediate neighbourhood of st. 39*a*.
[3]) Not given here.

TABLE 26. Oxygen content and hydrogen-ion concentration in the deep layers of Makassar strait.

In the south:

St. 30			St. 33		
D	O_2	pH	D	O_2	pH
1000	2.12	7.83	1194	1.99	7.94
1250	1.96	7.82	1433	2.03	7.92
1500	2.00	7.82	1670	1.95	7.93
1740B	*1.67*	*7.98*	1901B	1.88	*8.32*

In the narrowest part:						In the north:		
St. 35			St. 36			St. 41		
D	O_2	pH	D	O_2	pH	D	O_2	pH
1250	2.03	7.83	570	2.26	7.88	1500	2.13	7.87
1500	2.03	7.83	760	2.27	7.88	1750	2.11	7.87
1750	1.99	7.83	950	2.13	7.87	2000	2.14	7.83
1972B	1.89	*8.11*	1085B	*1.86*	*8.08*	2342B	2.10	*8.04*

St. 33 lies in the centre of the southern area; here too a decrease of the O_2-content was shown between the two lowest *serial* samplers which corresponds to that between 1670 m and the bottom. The increase in pH, however, is only conspicuous at the bottom, while the sample from the lowest of the serial water bottles showed no discontinuity in the pH.

The two stations 35 and 36 lie on the cross section in the narrowest part of the Strait; 35 in the centre, 36 near the coast of Celebes. At the first of these the decrease near the bottom is normal, at the last it is very considerable while at both stations the pH increases suddenly.

In the northern portion of the Strait the observations at st. 41 show little deviation from the serial observations; at the same time the pH increases rapidly.

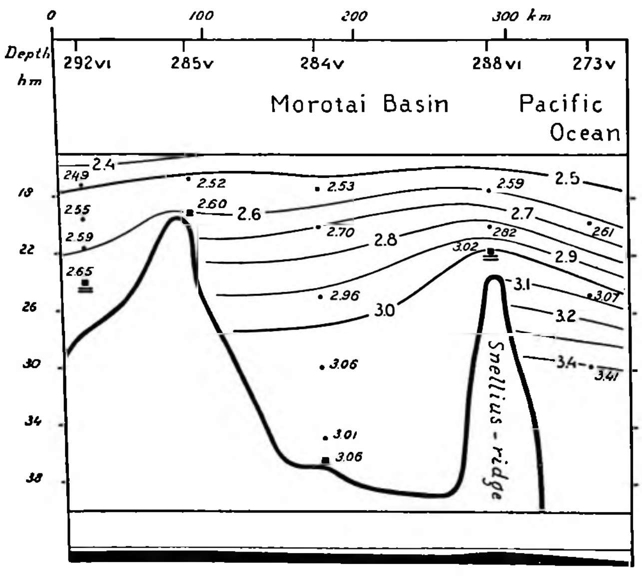


Fig. 7. The distribution of oxygen content along a vertical section across the Morotai basin.

2. *The Strait between the Talaud islands and the island of Halmahera.*

We now return to the Pacific Ocean and consider the renewal of the bottom water in the more

easterly situated basins and troughs through this most important entrance between the island of Halmahera and the Talaud islands. Here we are upon more secure ground, where the bottom water samples obtained with an ordinary serial water sampler are a better guarantee of the accuracy of the bottom observations.

Molukken sea. (fig. 7). The entrance from the Pacific Ocean into the Molukken sea is partly closed by the „Snellius" ridge. The water flows in over the threshold of this ridge (2340 m) with an O_2-content of fully 3.00 cc/L, so that in the contiguous basin (the Morotai-basin) at st. 284 a content of 3.06 cc/L was found near the bottom at 3651 m.

The Morotai basin is closed on the western side by a rise in the floor which connects the central ridge of the Molukken sea with the Talaud islands. Consequently the deep water flows southwards, so that the isoline for 3.0 cc reaches inwards in a tongue to about 1° N.lat. The water passes the threshold (2710 m) that divides the Morotai basin from the Ternate trough with this content. At st. 347 in this trough we accordingly find near the bottom a value of 3.04 cc/L. Fig. 8. (See also fig. 3).

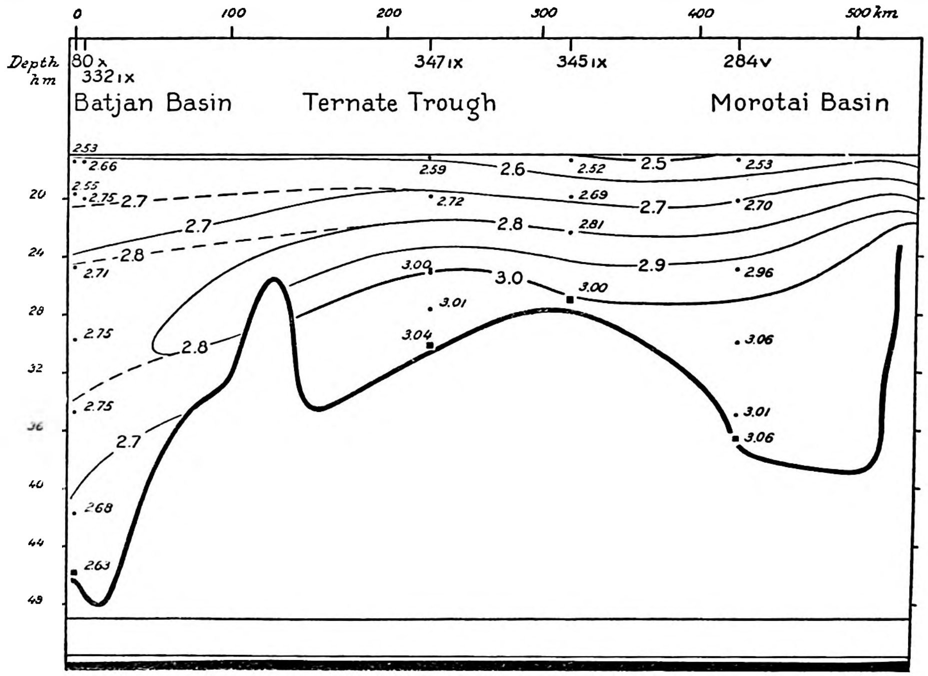


Fig. 8. The distribution of oxygen content along a vertical section from the Morotai basin to the Batjan basin. (Eastern Molukken sea).

The ridge between this trough and the Batjan basin (threshold depth 2550 m) prevents the further penetration of this high O_2-content southward to the Batjan basin. The isoline for 2.8 cc/L, however, extends over this threshold as far as north of Lifamatola strait, at st. 227 we still found near the bottom at 2967 m a value of 2.85 cc. (Compare the dotted isolines in figs. 8 and 11).

Probably the well ventilated bottom current from the north leaves st. 80 in the Batjan basin to the left, as here the content remains below 2.8 cc in the deep water and near the bottom at 4586 m 2.63 cc was found. From the Batjan basin the water flows westward by which the bottom water passes over a threshold at a depth of 2710 m before reaching the Mongole basin. The oxygen content of the threshold current is still more than 2.8 cc/L. Fig. 9.

From the Mangole basin the bottom water flows over a threshold at about 2700 m, where at st. 334 2.83 cc/L was determined at 2625 m and then enters the Gorontalo basin. This consists

of two separate depressions which are probably in connection down to a depth of 2970 m.

According to the temperature profile in fig. 7 of Vol. II Part 2 Ch. II the potential isotherm of 1°.95 C of the Mangole basin stretches over the threshold at st. 334 as far as the small north-eastern part of the Gorontalo basin and accordingly at st. 337, lying here, a potential temperature of 1°.95 C was found.

The oxygen profile of the deep water shows no such connection. With a potential temperature of 1°.95 C belongs an oxygen content of about 2.8 cc, while at the bottom at st. 337 it was certainly not more than 2.55. So far we had always noted in the Pacific water below the intermediate minimum an increase of the O_2-content with the depth; at station 337 in the deep layers the contrary was found. Apparently the Pacific bottom water flow, after having circulated the southern part of the central ridge of the Molukken sea, does not reach the small Gorontalo basin and flows between the two stations 336 and 337 parallel to and at some distance from the coast of Celebes, in a NNE-ly direction. This was confirmed by an oxygen cross section for stations 339, 338, 337, 336, 335 and 333 [1]).

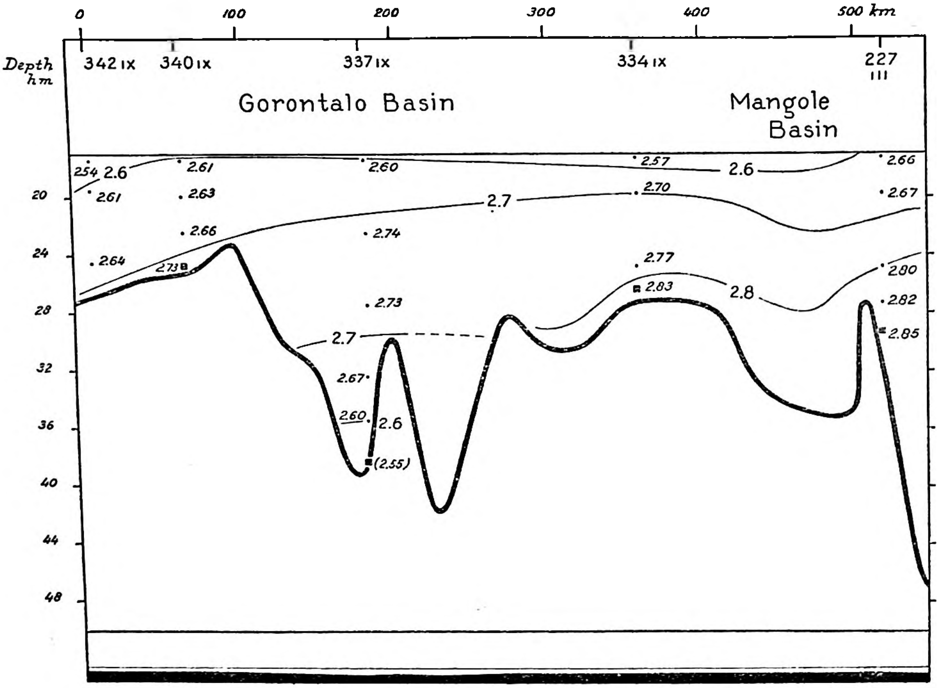


Fig. 9. The distribution of oxygen content along a vertical section across the Mangole basin and the Gorontalo basin (South-western part of the Molukken sea).

The isoline for 2.7 cc/L runs accross the northern enclosure of the Gorontalo basin northward as, at st. 340 near the bottom, in the axis of the narrow depression a content of 2.73 cc at 2477 m was still found. A supply of bottom water with an O_2-content of 2.7 cc/L from here to the Sangihe trough is in any case impossible as appears from the cross section of the observations at stations 290, 291, 292 and 286 between the Talaud and Sangihe islands [1]). The termination of the 2.6-line is here uncertain. Pl. I.

Fig. 10 shows the oxygen-depth curves for the deeper layers which flow from the Morotai basin (A) round the central ridge in the Molukken sea to station 340 (F), which lies in the narrow

[1]) Not given here.

marginal depression near the NE-point of Celebes. All bottom observations were made with a serial water sampler; at all stations the O_2-content near the bottom increases with the depth.

Ceram sea. We now follow the course of the bottom water into the Ceram sea. In fig. 11 the same vertical section is drawn as in Vol. II Part 2 Ch. II. On the north side of Lifamatola strait, lying between the Soela islands and Obi Major, the observations of both st. 227 and of st. 80 were entered. We have seen above that the well oxygenated deep water with a content of 2.8 cc passes st. 80 on the west side. In fig. 11 we find an apparently isolated area with more than 2.8 cc/L near the bottom at st. 227. The dotted lines show the connection of this isolated area with the water layers rich in oxygen, lying to the north-west; the full drawn lines are based on the observations at stations 80 and 332 in the Batjan basin [1]).

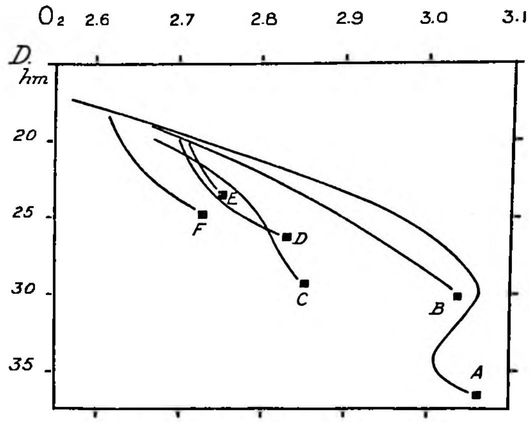


Fig. 10. Gradual change of the oxygen-depth curves from the Morotai basin, A st. 284, round about the central ridge of the Molukken sea to st. 340 (F) near the N.E. point of Celebes. B = st. 347 Ternate trough, C = st. 227 Batjan basin, D = st. 334 between Mangole and Gorontalo basin, E = st. 336 Gorontalo basin.

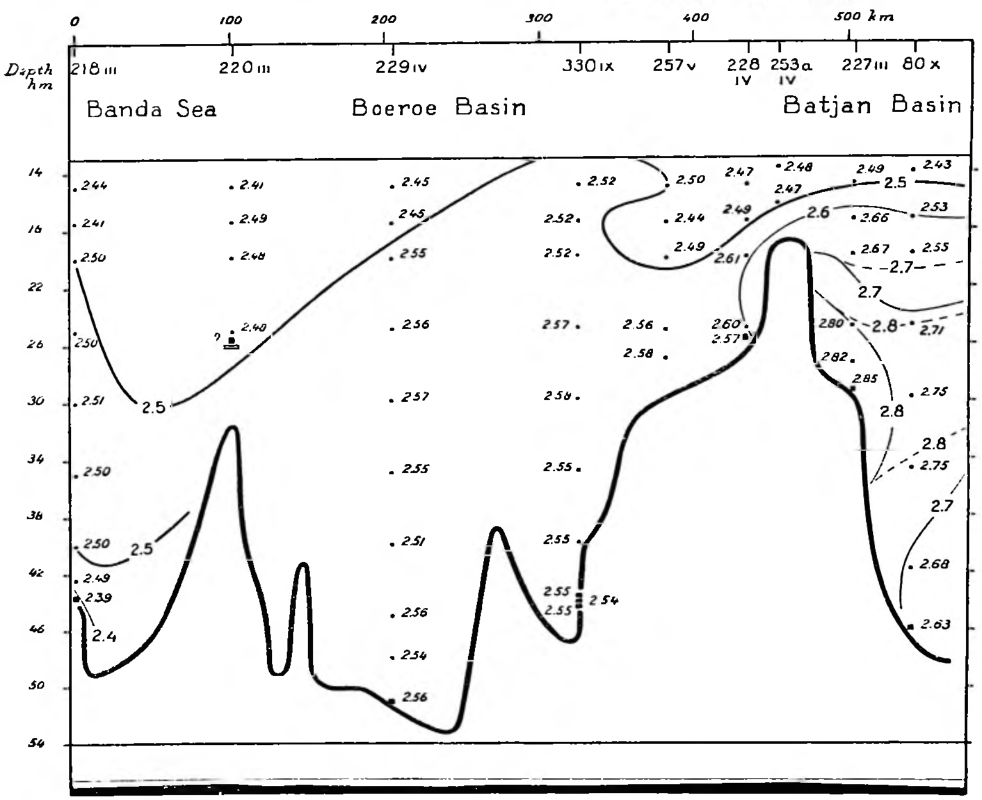


Fig. 11. The distribution of oxygen content along a vertical section from the Molukken sea (Batjan basin) to the Banda sea.

[1]) Fig. 11 shows the contents for st. 80 only. See also fig. 8.

From here the bottom water flows over a threshold in the Lifamatola strait (depth 1880 m) to the Boeroe basin — the deep basin in the western area of the Ceram sea — with an oxygen content of fully 2.6 cc/L. At st. 228 on the south side of the Strait at a depth of 2000 and 2500 m we found 2.61 and 2.60 cc respectively and a bottom observation of 2.57 cc. Even at the deepest stations we observed near the bottom an increase of the O_2-content with the depth. Neither does the bottom-pH show the least irregularity. A serial water sampler was used to haul up the water.

TABLE 27. Oxygen content and hydrogen-ion concentration in the deep layers of the Boeroe basin. St. 229.

D	O_2	pH	D	O_2	pH
2990	2.57	7.76	4490	2.56	7.78
3490	2.55	7.79	4790	2.54	7.80
3990	2.51	7.79	5100B	2.56	7.77

The whole Boeroe basin shows remarkably slight variations in the O_2-content from 1800 to 5000 m. The mean value is 2.55 cc/L. From the intermediate minimum lying above the threshold in Lifamatola strait a tongue of less then 2.5 cc stretches into the basin. In the direction of the Banda sea the O_2-content gradually diminishes.

Banda sea. Fig. 11. The ridge between the islands of Boeroe and Sanana has a threshold depth of 3130 m in the Sanana strait. The bottom current flows over the most southerly part of the threshold at the NW-point of Boeroe with a content of slightly more than 2.5 cc/L. This is not shown in the observations at st. 220, which only reach to 2600 m, but it may be seen in those from st. 221 lying just inside the threshold in the Banda sea. Here we found:

at 2500 m	2.45 cc
„ 3000 „	2.53 „
„ 3500 „	2.53 „
„ 3616 „ (B)	2.51 „

This bottom current does not seem to be continued towards the west, as at st. 218 near the bottom 2.39 cc was determined. At this station, indeed, somewhat higher above the bottom we again find an O_2-content of something more than 2.5. Presumably here near the bottom the effect is felt of the oxygen-poorer water from the west. The differences found, however, are very slight. Plate I shows a curvature of the bottom water movement to the south-west and south based upon the observations at stations 331 and 209.

TABLE 28. Oxygen content and hydrogen-ion concentration in the deep layers of the north-western part of the Banda sea.

St. 218			St. 209		
D	O_2	pH	D	O_2	pH
2000	2.50	7.77	1980	2.34	7.81
2500	2.50	7.80	2230	2.40	7.81
3000	2.51	7.76	2480	2.42	7.80
3500	2.50	7.77	2980	2.46	7.82
4000	2.50	7.75	3480	2.51	7.80
4250	2.49	7.75	3880	2.43?	7.80
4371B	2.39	—	4202B	2.53	7.81

In penetrating further into the Banda sea the O_2-content of the bottom water diminishes

slightly. Over a large part of this extensive area the content varies between 2.47 and 2.43 cc, so that the 2.4-line embraces almost the whole extent. In a few places only we find a deviation, for instance the 2.5-line appears again in the deepest part south of the Manipa strait, and the content falls below 2.4 in shallower portions.

The variations in the vertical direction are also insignificant. Fig. 12. In the northern basin this was shown for the deep water by the data from Table 28. The vertical distribution for the southern basin (st. 241) and the Weber deep (st. 321) appears from Table 29.

TABLE 29. Oxygen content and hydrogen-ion concentration in the deep layers of the southern and eastern part of the Banda sea.

Southern Banda basin			Weber deep		
St. 241			St. 321		
D	O_2	pH	D	O_2	pH
1980	2.40	7.76	1945	2.37	7.76
2480	2.35	7.78	2445	2.37	7.80
2980	2.42	7.78	2990	2.33	7.83
3480	2.39	7.80	3490	2.34	7.80
3980	2.42	7.80	3990	2.35	7.79
4480	2.44	7.78	4990	2.37	7.78
4796B	2.46	7.79	5990	2.37	7.82
			6592B	2.40	7.82

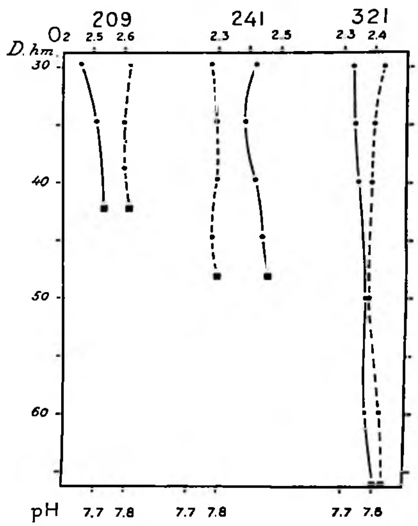


Fig. 12. Banda sea. Oxygen-depth and pH-depth curves in the northern (st. 209), southern (st. 241) and eastern part (st. 321) of the Banda sea. The dotted lines represent the pH-curves.

Owing to the small horizontal changes in the O_2-content the oxygen distribution throws little light upon the movement of the bottom water through the Banda sea. It is possible that an examination of the various oxygen profiles and the horizontal sections will yield more data, but we must leave this to others.

In the Banda sea, too, the *bottom* observations, carried out with an ordinary water sampler show no discontinuities in regard to the *serial* observations. To one point, however, we must draw the attention. In the immediate neighbourhood of the vulcano Goenoeng Api south-west of the Lucipara islands at st. 245 we found:

At 2490 m 2.43, at 2990 m 2.43 cc
„ 3490 „ 2.45, „ 3990 „ 2.46 „

and near the bottom at 4390 m 2.30 cc/L.

In drawing the isolines on Pl. I we disregarded this observation which was taken with an antiquated Sigsbee water sampler.

Wetar basin. From the bottom oxygen content of stations 369 and 370 it appears that the 2.4-line closes in the south-western area of the Weber deep. On Pl. I we see the line reappear, however, in the unsettled transition area between the Deep and the Wetar basin, lying to the north of the NE-point of the island of Timor. Probably this is due to the effect of bottom water coming directly from the Southern Banda basin and flowing over the threshold lying between the islands of Romang and Damar. In the vertical longitudinal section of fig. 13 there is, namely, an area bounded by the isoline for 2.4 cc that reaches to the bottom at st. 374; presumably this is also the case at st. 371. Moreover an O_2-content of 2.40 cc/L was determined at st. 377 at a depth of 2500 m and at 4000 m at st. 369. At the last station the O_2-content decreases towards the bottom to 2.37 cc/L at about 4500 m depth.

The threshold between Romang and Damar lies at a depth of about 3170 m (see depth chart

in Vol. II Part 2 Ch. II). At station 373 situated here no bottom observations were made; with the serial observations we found:

at 2000 m 2.38 cc, at 2500 m 2.43 cc and at 3000 m 2.48 cc.

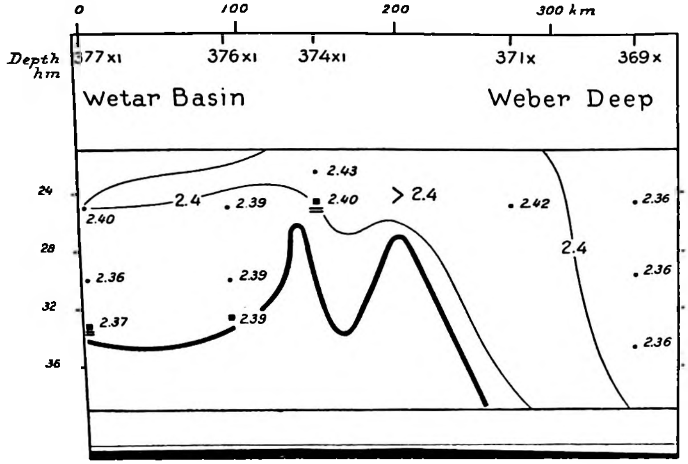


Fig. 13. The distribution of oxygen content along a vertical section across the passage between the Weber deep and the Wetar basin.

Probably the bottom water from the Weber deep unites with the direct flow from the Southern Banda basin. This water flows south of the ridge lying in the axis of the passage, and later passes the inner threshold with an O_2-content of about 2.4 at a depth of 2600 m. Fig. 13. At station 376 and 377 in the Wetar basin at the bottom 2.39 and 2.37 cc were found respectively. In the deep layers of the last named basin the contents below the niveau of 2000 m differ very little.

TABLE 30. Oxygen content and hydrogen-ion concentration in the deep layers at two stations in the Wetar basin.

St. 376			St. 377		
D	O_2	pH	D	O_2	pH
1250	2.37	7.77	1250	2.32	7.79
1500	2.39	7.75	1500	2.33	7.77
2000	2.38	7.76	2000	2.35	7.79
2500	2.39	7.75	2500	2.40	7.77
3000	2.39	7.76	3000	2.36	7.78
3259B	2.39	7.76	3314B	2.37	7.76

As in the Banda sea, in the Wetar basin we find no discontinuity in the vertical oxygen distribution near the bottom. The bottom observations were made with an ordinary water sampler.

Sawoe sea. As can be seen in Vol. II Part 2 Ch. II p. 47 the renewing of the bottom water in the Sawoe sea takes place through the narrow Ombai strait, lying between the islands of Timor and Kambing. In doing so the bottom water passes a threshold 2100 m below the surface of the sea. Fig. 14.

All the bottom observations in the Sawoe sea were made with a reversing bottom water sampler, except those at st. 381. A correction of +0.1 cc was applied to the values found for depths below 1500 m. At st. 162 near the threshold we found at the bottom at 1977 m depth a corrected O_2-

content of 2.01 cc, while at st.377 at 40 sea miles east of the threshold in the Water basin, at the same depth 2.35 cc and near the bottom at 3314 m 2.37 cc/L was observed. Such a rapid decrease of the oxygen content in the direction of Ombai strait raises some doubt as to the reliability of the bottom observation above the threshold in the Strait. This is the more probable as the other bottom observations at st. 162 also proved unreliable.

In the Sawoe basin, as in the Celebes sea, we noted sudden changes in the O_2-content naer the bottom, Table 31. These are considerable at the deep stations, but with a correction of + 0.1 cc they became less significant at a depth of about 2000 m.

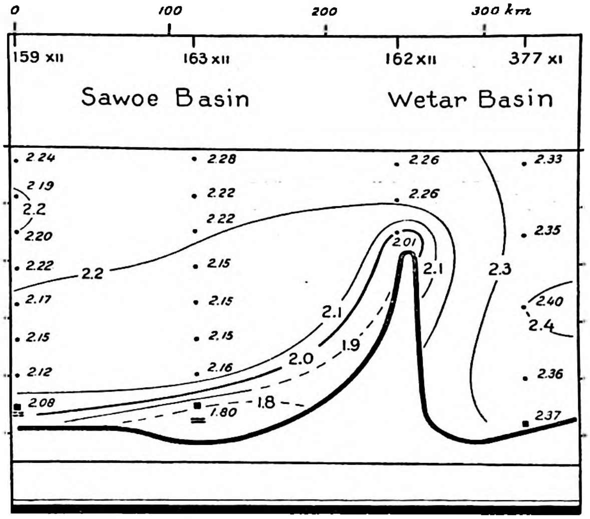


Fig. 14. The distribution of oxygen content along a vertical section across Ombai strait, the narrow passage between the Wetar basin and the Sawoe basin.

TABLE 31. Oxygen content and hydrogen-ion concentration in the deep layers at four stations in the central part of the Sawoe basin.

St. 163			St. 160			St. 155			St. 153		
D	O_2	pH	D	O_2	pH	D	O_2	pH	D	O_2	pH
2480	2.15	7.80	2500	2.26	7.81	2740	2.09	7.79	2250	2.21	7.80
2980	2.15	7.79	2750	2.05	7.79	2990	2.11	7.79	2500	2.18	7.81
3180	2.16	7.80	3000	2.03	7.80	3190	*1.86*	7.80	2750	2.17	7.81
3265B	*1.80*	*8.02*	3190B	*1.89*	*7.94*	3267B	*1.67*	*7.90*	2897B	*2.04*	*7.90*

From the above data and fig. 15 the change in O_2 appears to be very great at st. 155 situated *in the middle of the basin.* But here the *serial observation* at 3190 m also show an important decrease as

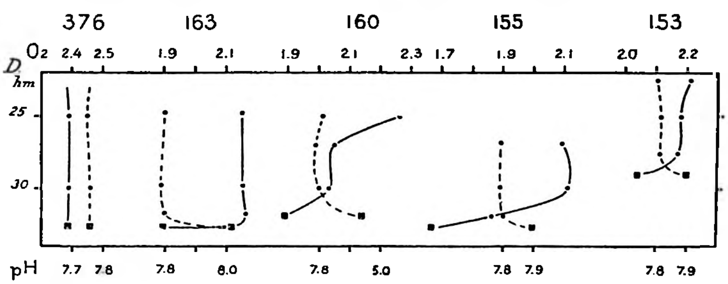


Fig. 15. Oxygen-depth and pH-depth curves in the Sawoe sea (sts. 153, 155, 160 and 163) and in the Wetar basin (st. 376). The dotted lines represent the pH-curves.

compared to the observations at 2990 m, so that it may be assumed that the rapid change near the bottom is not only to be attributed to an oxidation of the reversing bottom water samplers. In

the pH-values (dotted line in fig. 15) we see that a rapid increase near the bottom is accompanied by a decrease of O_2, as was recorded above in the Celebes sea [1]).

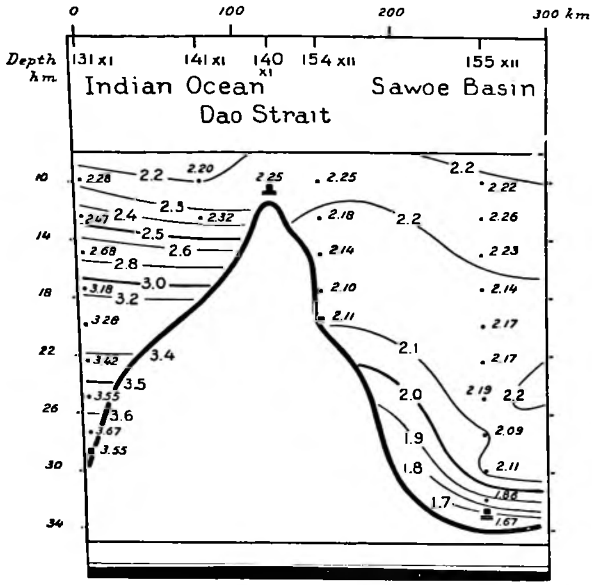


Fig. 16. The distribution of oxygen content along a vertical section across Dao strait.

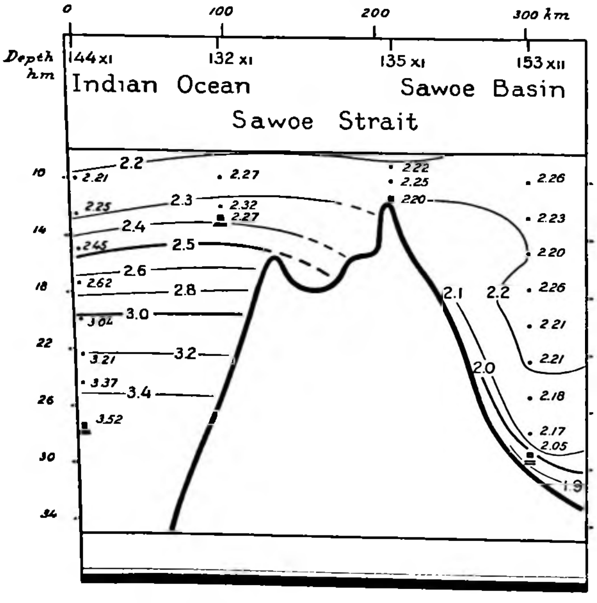


Fig. 17. The distribution of oxygen content along a vertical section across Sawoe strait.

On the inner side of the thresholds of the Dao and Sawoe straits the O_2-content near the bottom appears also to be small according to figs. 16 and 17. At about 1950 m depth (fig. 14) the water flowing over the threshold in Ombai strait to greater depths with an O_2-content of about 2.15 cc, turns back according to fig. 16 at about 1800 m and returns to the middle of the basin. This returning current affects st. 159 (fig. 14) where the O_2 at 1800 m declines just below the content of 2.2 cc. The isoline for 2.2 cc where it is broken off in fig. 14 at 2000 m and 2400 m corresponds with the same line drawn in fig. 16 near st. 155 at 2500.

Presumably the supply of oxygen in the deep water through the Ombai strait is insufficient. As has been shown in Vol. II Part 2 Ch. II there is no possibility of a renewing of the bottom water from the Indian Ocean, the oxygen profiles through the Straits of Dao and Sawoe, figs. 16 and 17, support this conclusion. In these Straits the thresholds which divide the Sawoe basin from the Indian Ocean lie at 1200 m depth. The entrance north of the island of Soemba is still shallower and only 900 m deep.

In fig. 18 we give the oxygen-depth curves for the deep layers in the successive areas between the south part of the Molukken sea, A st. 227 and the Sawoe sea, G. st. 155. The dotted line above on the right in the figure shows the niveau of the threshold in Lifamatola strait which connects the Molukken sea with the Ceram sea.

The increase of O_2 with the depth in the Pacific water of the Molukken sea diminishes in the successive basins. The O_2-content near the bottom becomes successively less. The curves B to E lie close

[1]) See also p. 46.

together owing to the great depth at which the different areas are connected with one another.

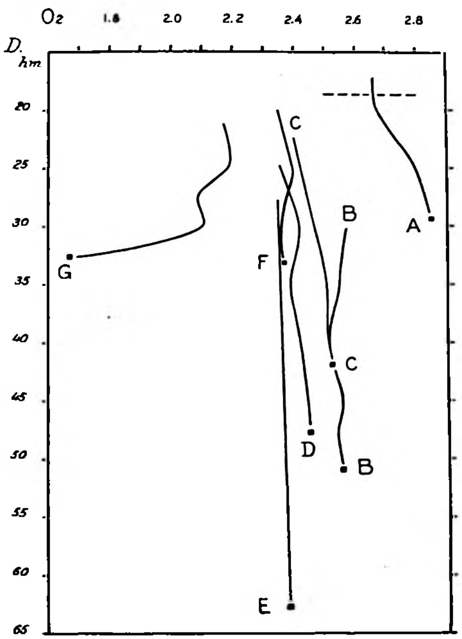


Fig. 18. Gradual change of the oxygen-depth curves from the Molukken sea, A st. 227, to the Sawoe sea, G st. 155. Ceram sea = B st. 229, Northern Banda sea = C st. 209, Southern Banda sea = D st. 241, Weber deep = E st. 365, Wetar basin = F st. 377.

At st. 155 in the centre of the Sawoe sea, curve G, the O_2-content near the bottom declines very rapidly as shown not only by the bottom observations but by the serial observations at 3190 m as well. Curve E, almost a straight line, shows the very gradual increase of the O_2-content in the Weber deep.

Gulf of Bone, Salajar trough. Returning to the Banda sea, in the south-western area we find that the bottom water penetrates south of the island of Kababia through a deep channel and over the threshold between that island and Batoeata into the Gulf of Bone with an O_2-content of more than 2.3 cc. From the latter area the bottom water is apparently renewed in the narrow and deep Salajar trough over the ridge which connects the plateau of the Tyger islands with Celebes. Here at st. 187 at 3065 m 2.21 cc was determined. (uncorrected 2.11 cc). Table 32.

TABLE 32. Oxygen content and hydrogen-ion concentration in the Gulf of Bone, st. 192, and in the Salajar trough. St. 187.

St. 192			St. 187		
D	O_2	pH	D	O_2	pH
1990	2.28	7.81	2500	2.22	7.75
2240	2.28	7.81	2750	2.17	7.79
2390	2.32	7.80	3000	2.18	7.80
2519B	2.38	7.91	3065B	2.21	7.94

East of the island of Salajar we found at st. 186 near the bottom at 1368 m 2.35 cc/L. The bottom observations were made with a reversing bottom water sampler; a correction of + 0.1 cc/L was applied to the O_2-content.

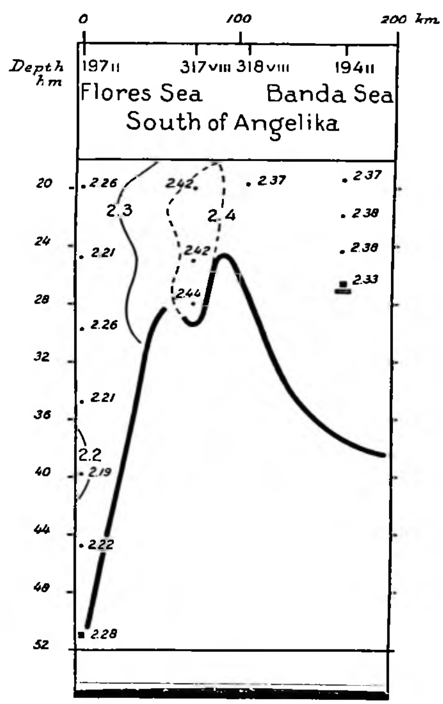


Fig. 19. The distribution of oxygen content along a vertical section across the passage between the Banda sea and the Flores sea.

Flores sea, Bali sea. Over the uneven floor of the transitional area between the Banda and Flores seas a second tongue of the isoline of 2.3 cc stretches out westwards. Here the bottom water probably flows between the small island of Soekoen and the Angelika shoals into the Flores sea. The vertical profile running along this passage is drawn in fig. 19. It shows that at st. 317 the serial

observations yielded a content slightly more than 2.4 cc. At 2800 m, that is 100 m above the bottom, we even found 2.44 cc, so that it is possible that near the bottom the content may be something more than 2.4 cc and that the isoline of 2.4 cc terminating on Pl. I in the south-western portion of the Banda sea stretches further westwards to near the threshold.

A bottom O_2-content of 2.4 cc/L was not found in the Flores basin. The highest value was 2.35 cc at 2799 m depth at st. 181 in the south near the NW-point of the island of Flores. Apparently the content diminishes towards the central deeper part while to the north it first increases and then declines. In the centre at a bottom depth of 5033 m we found at 5000 m with a serial observation 2.16 cc and with a bottom observation at 4970 m 2.04 cc. The latter was carried out with a Sigsbee sampler and is not entirely reliable. At the southern side of the basin the O_2-content near the bottom rapidly diminished towards the coast. The bottom observations at st. 168 were not used in constructing the isolines because of the extraordinarily rapid decline near the bottom which does not agree with the vertical distribution at st. 167 lying in the immediate neighbourhood. Table 33.

TABLE 33. Oxygen content and hydrogen-ion concentration of the deep layers at two stations in the Flores sea.

St. 168			St. 167		
D	O_2	pH	D	O_2	pH
1500	2.18	7.81	2480	2.24	7.80
2000	2.22	7.81	2730	2.24	7.80
2400	2.25	7.81	2980	2.24	7.80
2528B	*1.69*	*8.03*	3230	2.23	7.81
			3417B	2.29	7.85

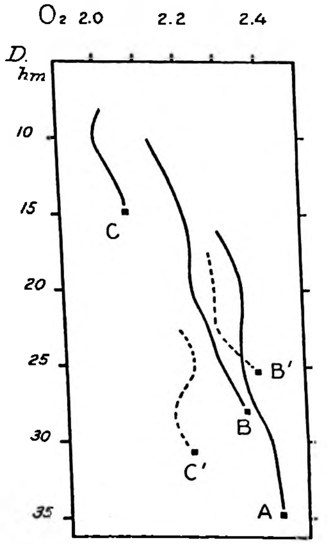


Fig. 20. Gradual change of the oxygen-depth curves from the south-western part of the Banda sea, A st. 203, to the Flores sea, B st. 181, and the Bali sea, C st. 173 on the one side and to the Gulf of Bone, B′ st. 192 and the Salajar trough, C′ st. 187, in a north-westerly direction.

Towards the Bali sea the O_2-content declines gradually, so that to the north of the island of Lombok the bottom water contains only 2.06 cc. In the shallower area between the Bali sea and Makassar strait with its numerous reefs and islands the content near the bottom again rose at five stations from 2.2 tot 2.4 cc/L to become 3 to 4 cc/L in the shallower Java sea.

We will compare in fig. 20 the oxygen-depth curve of the deep layers in the south-western area of the Banda sea (A) with those in the basins to the west and north-west. All the curves indicate an increase of the O_2 with the depth. From the Banda sea the content in both directions declines. With the exception of st. 203 (curve A, fig. 20) the bottom observations were carried out with a reversing bottom water sampler, so that here a correction of +0.1 cc is applied for depths of more than 1500 m.

Aroe basin. We must now investigate whether the O_2-content of the deep water in the Aroe basin is affected by the water from the Ceram sea. Fig. 21 represents the oxygen distribution in a vertical section running from st. 325 in the Ceram sea into the Aroe basin, through the deepest part in the north of the fairway. In Vol. II Part 2 Ch. II at pp. 52 and 53 we made the conjecture that the bottom water in the Aroe basin is renewed by water from the Timor sea, passing a threshold to the east of the Tanimbar islands at a depth of at most 1400 m. We will now examine in how far the distribution of oxygen in the bottom flow from the Ceram sea confirms this supposition.

In fig. 21 and Pl. I we see the O_2-content of the deep water gradually decline towards the east; probably the isoline of 2.5 cc reaches as far as st. 90 near the bottom. Here, however, the bottom observation is missing. After passing the threshold between sts. 90 and 324, depth about 1480 m, the content declines further so that in the narrow channel off Cape van den Bosch (st. 95) only 2.32 cc was found.

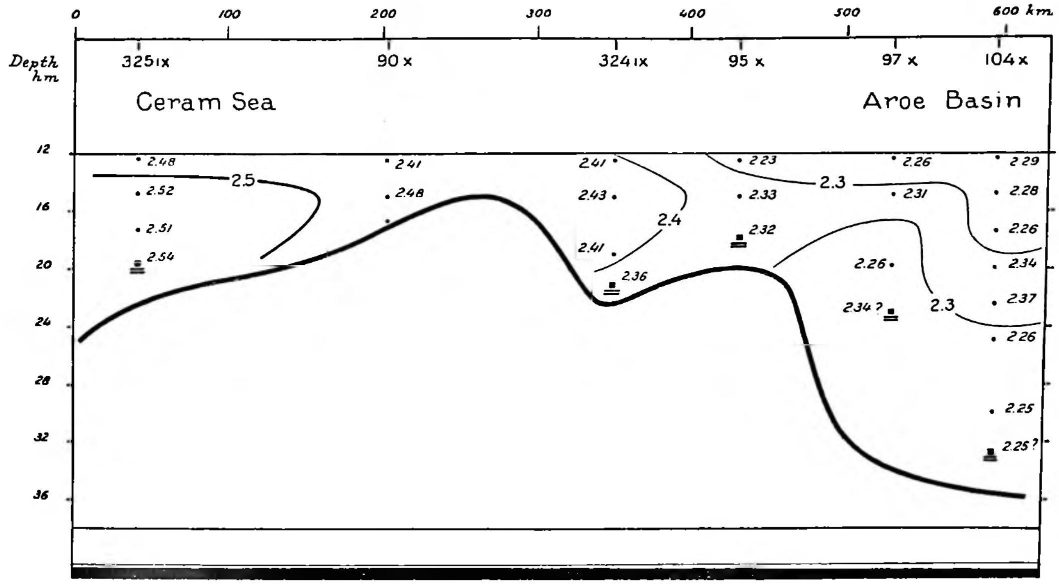


Fig. 21. The distribution of oxygen content along a vertical section across the passage between the Ceram sea and the Aroe basin.

From here the depth water probably no longer follows the sea floor but flows at a higher level in a south-easterly direction which explains the intermediate maximum at stations 97 and 104. It will be seen below, when considering the influence of water transport from the Indian Ocean, that the bottom water in the basin originates from this Ocean so that both kinds of water lie one above the other, pp. 63—65.

There is some doubt about the O_2-content of the bottom water at st. 97. An amount of 2.24 cc/L was determined which after a correction of +0.1 cc yields a value of 2.34 cc. Probably in this case the correction was too large considering the general O_2-distribution in the north-westerly area of the Aroe basin.

3. *The passage between the islands of Halmahera and New Guinea.*

We now return to the Pacific Ocean to consider finally the last of the three entrances which leads to the Halmahera sea. Here we again have at our disposal bottom observations carried out with the ordinary bottom water sampler, which deserve our full confidence and to which therefore the correction of +0.1 cc was not applied.

Halmahera sea. In Vol. II Part 2 Ch. II on p. 33 we came to the conclusion, according to the distribution of the potential temperature and the salinity, that the bottom water in this area of the sea was renewed by the transport of water from the Pacific Ocean. This water flows over an outer threshold at a depth of about 700 m lying between stations 351 and 352, after which an inner threshold is passed at a depth of some 940 m. Fig. 22.

In the Pacific Ocean we found [1]) an intermediate minimum of 2.31 cc at 1000 m depth; from this niveau the O_2-content increases rapidly in the higher layers, so that the content of the deep water in the Halmahera basin is 2.92 tot 2.95 cc/L. Here as we see, the bottom observations with the serial

[1]) At st. 350.

water sampler show no abnormal changes in the oxygen content near the bottom. A content of 2.95 cc in the bottom water cannot be accounted for by a transport from the Ceram sea, as we observed in the southern entrance at st. 354:

at 400 m 2.86, at 500 m 2.82 and at 546 m (bottom) 2.77 cc.

It is true that according to the oxygen profile water penetrates over this threshold from the Ceram sea; however, it does not appear to follow the bottom but is in equilibrium at a higher level. Between 800 and 1400 m the well oxygenated depth water from the Pacific Ocean mixes with the oxygen-poor water from the Ceram sea. The representation found in fig. 22 explains the slight decline of the O_2-content at st. 352 between 400 and 800 m depth. If this be ascribed to the influence of Pacific water the isolines cannot be drawn without constraint.

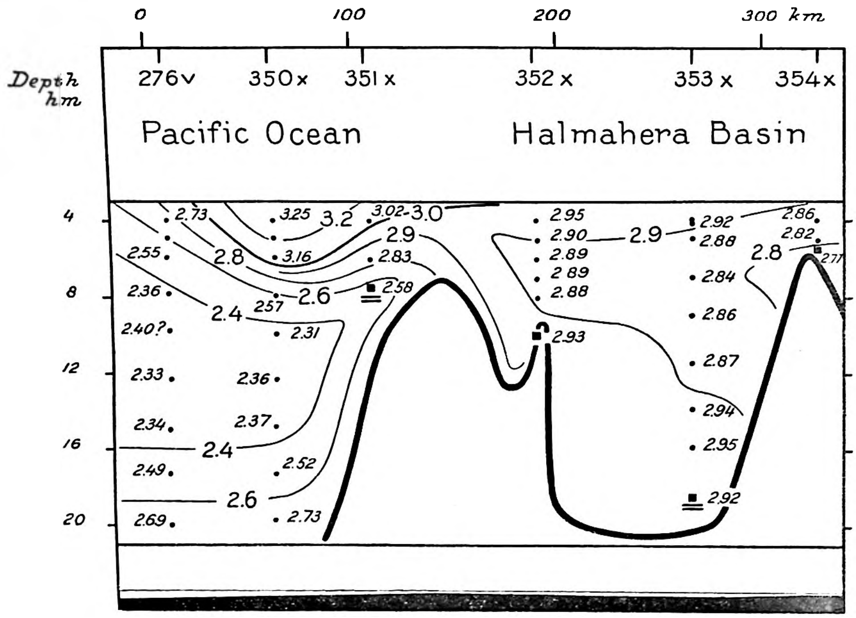


Fig. 22. The distribution of oxygen content along a vertical section across the Halmahera basin from the Ceram sea to the Pacific Ocean.

The above conclusion concerning the effect of the water from the Ceram sea cannot be drawn from the potential temperature and salinity distribution, fig. 13, p. 32; Vol. II Part 2 Ch. II. Here, therefore, the oxygen distribution lends welcome aid.

Kaoe bay. Finally there is a small bay with greatest depth of about 500 m, which lies in direct connection with the Pacific Ocean; the water is transported accross the threshold at 40 to 50 m depth. This is the only entrance. Fig. 23 shows the oxygen distribution in a vertical profile accross the threshold, from which it is seen that the oxygen content at the two stations 278 and 280, below the intermediate maximum at 75 m, rapidly declines with the depth, so that at the niveau of 350 to 400 m there is no more oxygen. Four observations at st. 278 below this level indicate the presence of 0.08 to 0.30 cc/L hydrogen sulphide. *The pH varies little in the deepest layers.* Table 34.

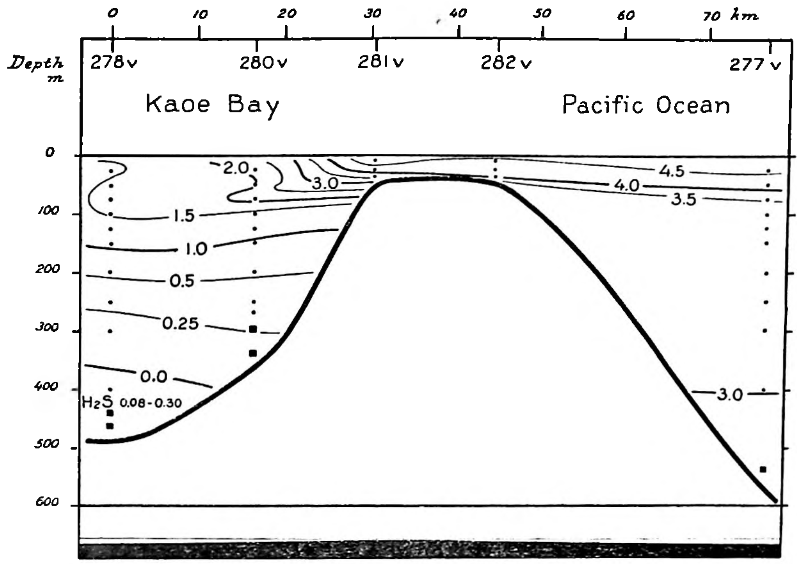


Fig. 23. The distribution of oxygen and hydrogen sulphide content along a vertical section across the shallow passage between the Pacific Ocean and the Kaoe bay. (N. E. Halmahera).

TABLE 34. Oxygen content, hydrogen-ion concentration and hydrogen sulphide content at st. 278 in the Kaoe bay. One set of serial observations and two wire soundings, depths 474 and 491 m.

D m	O_2 cc/L	pH	H_2S cc/L
0	—	8.40	—
25	1.32	8.17	—
50	1.66	8.17	—
75	1.84	8.22	—
100	1.54	8.19	—
125	1.42	8.21	—
150	1.06	8.15	—
200	0.62	8.11	—
250	0.29	8.10	—
300	0.13	8.07	0.00
400	0.00	8.03	0.08
401B*	0.00	8.04	0.09
431B*	0.00	8.05	0.09
441B	0.00	8.01	0.30
461B*	0.00	8.01	0.16

* Multiple bottom observations, depth 491 m.

On the roads of Akeselaka we found in the east of the bay, anchored at a depth of 35 m:

D m	O_2 cc/L
2	4.73
10	3.63
25	2.03

b. Influence of the Indian Ocean water.

The Indian Ocean. In the above the influence of water from the Pacific Ocean upon the oxygen distribution in the bottom water in the majority of the basins and troughs of the Archipelago has been dealt with. We now turn to the Indian Ocean. Here at the most southerly station, 146, we found a bottom content of 4.32 cc/L at a depth of 5340 m. In the direction of the coast the content near the bottom gradually diminished.

Vertically the O_2-content gradually increases with the depth from the minimum at about 600 m. No important changes were found at the bottom, after a correction of +0.1 cc had been applied to observations made with the reversing bottom water sampler, with the exception of sts. 145 and 147.

TABLE 35. Oxygen content and hydrogen-ion concentration in the deep layers of the Indian Ocean at the stations 145, 146 and 147.

St. 145			St. 146			St. 147		
D	O_2	pH	D	O_2	pH	D	O_2	pH
4980	4.28	7.96	3975	4.22	7.92	2490	3.46	7.85
5230	4.29	7.95	4475	4.33	7.91	2990	3.66	7.86
5480	4.27	7.94	4975	4.28	7.92	3490	3.90	7.86
5661B	*3.97*	*8.08*	5340B	4.32	7.97	3644B	3.85	*8.00*

From the figures in Table 35 it will be seen that both the O_2-content and the pH at st. 145 change very rapidly near the sea floor. There were three observations 30, 60 and 90 m from the bottom. The lowest sampler was filled with muddy water, so we used the water from the second sampler. The top sampler gave for the O_2 at 5631 m depth 3.99 cc, that is 4.09 cc corrected (pH 8.01); the bottom one, a Sigsbee water sampler gave 2.66 cc (no pH). Probably these data are not very reliable. Neither do the salinity results correspond to those of the lowest serial observations [1]). The bottom water at st. 147, however, also shows a deviation viz. a slight drop of 0.05 cc (actually 0.15 cc) while the content of the water samples from the serial samplers showed a considerable increase with the depth. Moreover the sudden increase of the pH near the bottom at this station was by no means negligeable.

Timor trough. The deep elongated depression between the Sahoel shelf and the islands of Timor and Roti according to the depth determinations is divided from the Indian Ocean, by an inner and outer threshold lying close together at 1940 and 1970 m respectively. In fig. 24 a longitudinal section is drawn between stations 125 and 131 along the axis of the trough. According to the course of the isolines (Pl. I) the line of 3.2 cc ends at the inner threshold, while the 3.1-line probably extends over the threshold to midway between stations 156 and 127.

A correction of +0.1 cc was applied to the bottom values found; probably the bottom observation near the threshold at station 156 is a little too low. For this station we found:

St. 156	
D	O_2
1240	2.37
1490	2.62
1735	2.92
1810	3.05
1825(B)	2.99

Within the threshold at st. 125 we see the O_2-content near the bottom diminish slightly; but

[1]) p. 36.

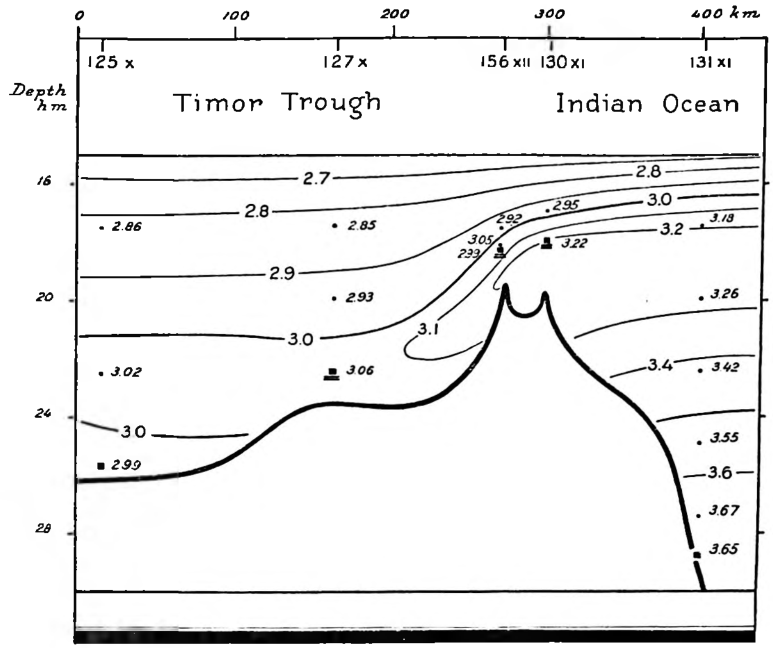


Fig. 24. The distribution of oxygen content along a vertical section across the passage between the Indian Ocean and the Timor trough.

the differences are very small. The discontinuity near the bottom at st. 118, where there is a local depression of the sea floor, is more important. Here we determined:

St. 118	
D	O_2
2000	2.88
2250	2.93
2500	2.93
2750	2.95
2812B	*2.62*

As the correctness of the bottom observation is not certain no separate isoline for 2.7 cc is drawn on Pl. I. Further eastwards we see the oxygen content in the axis diminish very gradually with a rapid decline towards the borders of the trough.

Aroe basin. For the connection of the Timor trough with the Aroe basin, concerning the O_2-content we refer to the longitudinal section in fig. 25. The two areas are divided from one another by a threshold at a depth of 1400 m to the south-east of the Tanimbar islands. The water penetrates the Aroe basin over this threshold with an O_2-content of about 2.35 cc. In the basin at the deep stations 100 and 104 we found:

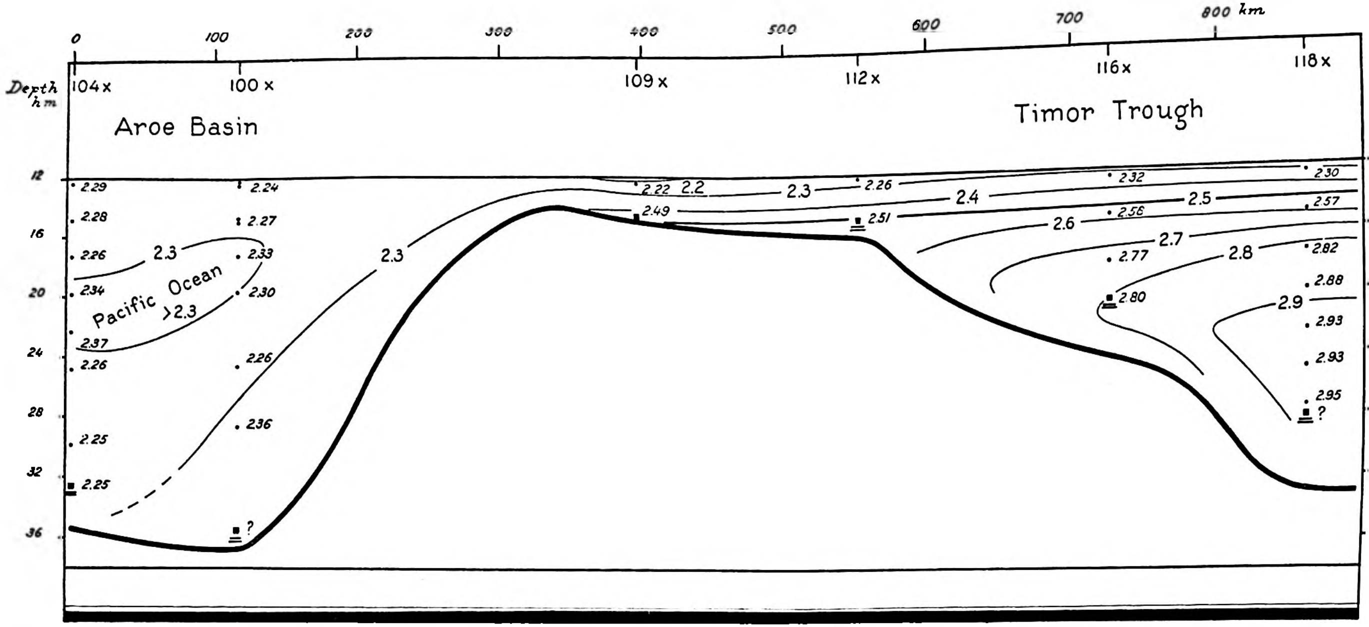


Fig. 25. The distribution of oxygen content along a vertical section across the passage between the Timor trough and the Aroe basin. (See also figs. 21 and 26).

TABLE 34. Oxygen content and hydrogen-ion concentration in the deep layers of the Aroe basin at the stations 100 and 104.

St. 100			St. 104		
D	O_2	pH	D	O_2	pH
1225	2.23	7.82	1238	2.29	7.84
1470	2.25	7.82	1458	2.28	7.85
1720	*2.33*	7.83	1740	2.26	7.85
1970	*2.30*	7.84	1990	*2.34*	7.84
2470	2.26	7.83	2240	*2.37*	7.82
2870	*2.36*	7.85	2490	2.26	7.86
3563B	1.67?	8.11?	2990	2.25	7.83
			3265B	2.25	7.96

A correction of +0.1 cc was applied to the observed bottom O_2-content. The values in italics of sts. 100 and 104 indicate an intermediate maximum. These high contents support one another and cannot be accounted for by casual inaccuracies. A longitudinal section over the stations 325, 95, 97, 104 and 100, see fig. 21, shows that we here have a transport of water from the Ceram sea. From the cross-section in the Aroe basin between the Kai islands and the Aroe islands along stations 98, 99, 100, 101 and 102 (Fig. 26) it appears that the better oxygenated water from the Ceram sea between 1600 m and 2000 m extends *over the whole breadth of the trough* [1]).

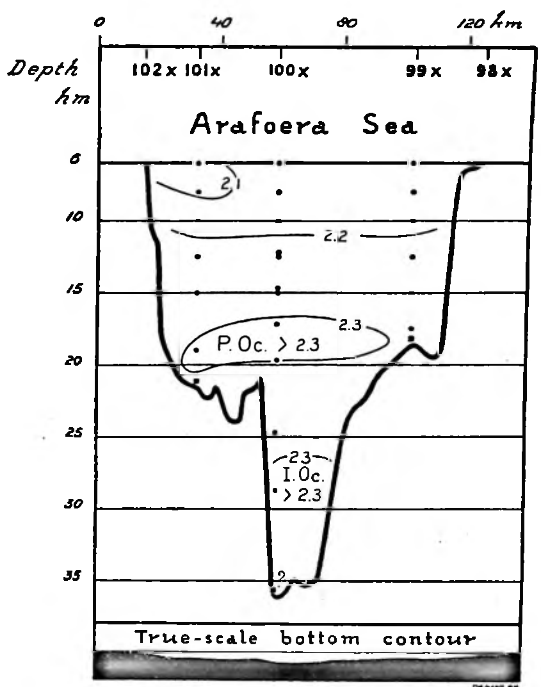


Fig. 26. The distribution of oxygen content along a vertical section across the Aroe basin.

Now at st. 100 we find a second maximum at 2870 m, which might be due to a backward curve in the transport from the Ceram sea at a lower level, but it is more logical to ascribe this increase in the deepest water to the effect of the bottom current from the Timor sea which passes the threshold east of the Tanimbar islands. [1]) In that case the properties of the deep water (2870 m) at st. 100 must correspond with those of the water above this threshold at st. 109.

For examining this we will consider the potential temperature, the oxygen content and the salinity; we have therefore drawn in fig. 27 tp—O_2 and tp—S curves based on the observations of st. 109 for the depths 1000 m, 1250 m and 1473 m (bottom). The tp—O_2 curve is indicated by a dotted and the other by a full drawn line. A circle and a cross show the corresponding values determined at st. 100 at 2870 m. Apparently the latter agree with the values found at a depth of about 1360 m at st. 109, that is to say, at about 40 m above the threshold. In accordance with these data a separate 2.3 line is drawn on the left of fig. 25 which indicates a ventilation of the bottom water by the introduction of water from the Timor sea.

[1]) See „Additions and corrections" printed on the loose sheet enclosed in this paper.

The low O_2-content at st. 100 near the bottom is uncertain; neither are the temperature and salinity to be relied upon. As is shown by the multiple bottom observations on p. 36 this is also the case with the observations at 31 m and 61 m above the bottom at st. 104, also lying in the deep area of the Aroe basin, so that at that station the observation at a distance of 91 m above the bottom was used in drawing Pl. I.

It is therefore not impossible that at a smaller distance from the floor in the deep part of the basin there is an area poor in oxygen, such as was found in the Flores and the Sawoe basins [1]).

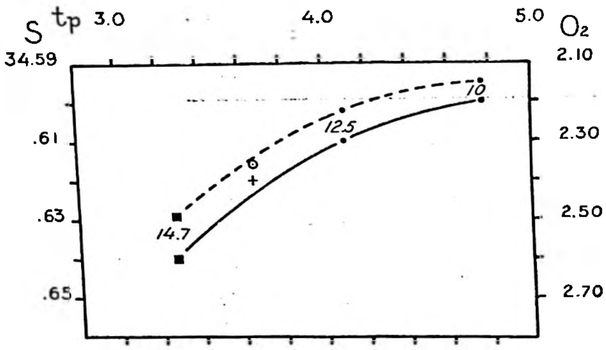


Fig. 27. Comparison of the salinity, the potential temperature and the oxygen content at st. 100 in the Aroe basin at a depth of 2870 m with the tp-O_2 and tp-S curves of st. 109, situated near the threshold which separates the Aroe basin from the Timor trough. Dotted line = tp-O_2 curve.

c. Influence of the South China Sea water.

Finally we will examine the effect of the transport of water from the South China sea to the Sulu sea.

Sulu sea. The bottom observations in the Sulu sea were carried out with a reversing bottom water sampler, so that a correction of +0.1 cc/L was applied to them. Probably the influence of the oxidation of the sampler furthered by the higher temperature down to great depths (about 10°C) has had more effect on the O_2-content than in the other basins. But we have in the Sulu sea no observations with a serial water sampler for comparison, so that we must be content with the application of a correction determined elsewhere at lower temperature. But even after this correction the O_2-content at the deep stations proves to diminish rapidly, as appears from table 35.

TABLE 35. Oxygen content and hydrogen-ion concentration in the deep layers of the Sulu sea at stations 63, 64 and 65.

St. 63			St. 64			St. 65		
D	O_2	pH	D	O_2	pH	D	O_2	pH
1500	1.43	7.93	1470	1.37	7.95	1500	1.39	7.91
2000	1.47	7.92	1990	1.36	7.96	2000	1.47	7.92
2500	1.52	7.94	2990	1.52	7.99	3000	1.59	7.96
2800	1.55	7.95	3990	1.57	8.00	3700	1.62	7.96
3036B	*0.65*	*8.19*	4268B	*0.57*	*8.30*	3950	*1.30*	*8.17*

Thus we see here, too, near the bottom a rapid decrease of the O_2-content accompanied by a considerable increase of the pH. Pl. I, however, shows that the bottom oxygen content increases systematically towards the south. Concerning st. 66 we refer to: „multiple bottom observations" on p. 36.

The vertical section of fig. 28 [2]) shows that the renewing of the bottom water in the Sulu sea does not take place from the Celebes sea by a transport through the Sibutu strait and along Pearl Bank — at any rate not in the month of September. The isolines run almost horizontally from the

[1]) See: Multiple bottom observations p. 36.

[2]) The O_2-content of 2.15 given in Fig. 12 of Vol. II Part 2 Ch. II at st. 73 at 600 m should be 2.32. The isolines in our figure 28 are revised accordingly.

Sulu sea over the northern threshold up to the threshold at 270 m depth in the Sibutu strait. Here we find a rapid increase of the O_2-content with the transition to the water of the Celebes sea, which

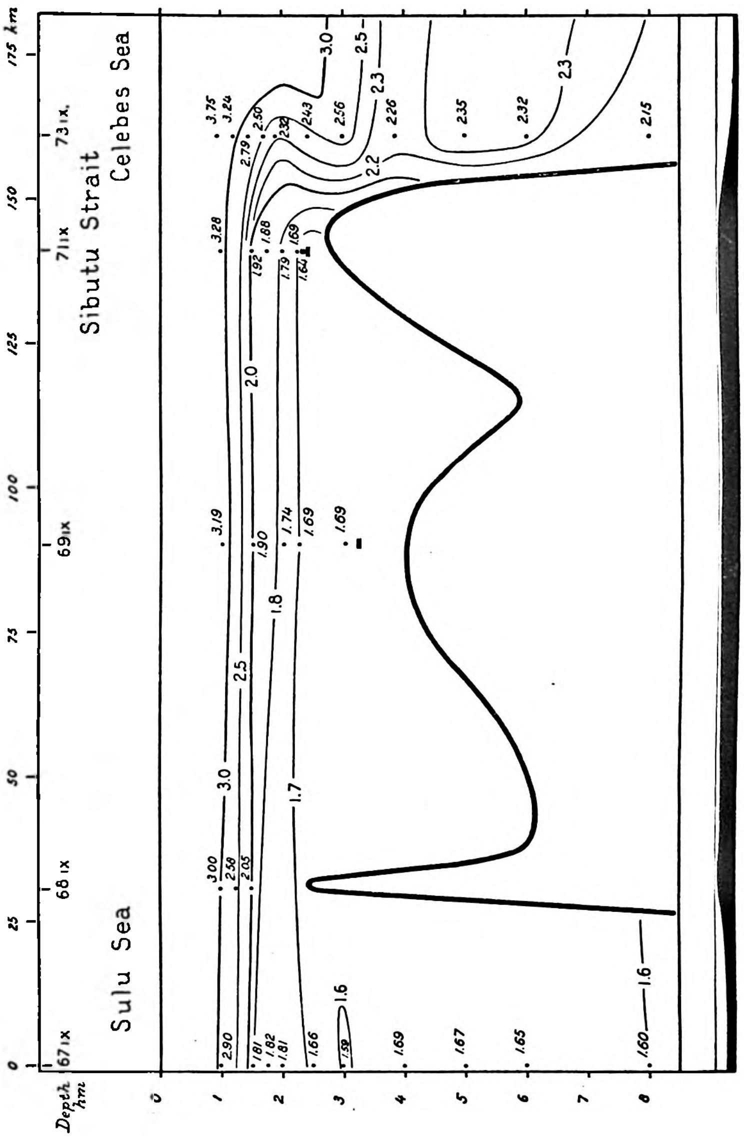


Fig. 28. The distribution of oxygen content along a vertical section in the passage which connects the Celebes sea with the Sulu sea.

would not be observed with a water transport in the opposite direction. Moreover that would be in contradiction with the current observations which were carried out during the research in the Strait.

d. **Comparison of the O_2-content near the bottom in the various basins with the mean content determined for corresponding depths in the open sea.**

When examining the distribution of oxygen in the bottom water (Pl. I) we are at once struck by the difference of oxygen content in the various basins.

Sulu sea. The ventilation of this basin must take place principally from the South China sea through a Strait about 400 m deep, south-west of the island of Mindoro. When considering whether this ventilation may be adequate it must be remembered that the Sulu basin within the depth of 4000 m covers an area of 46000 km² with a greatest depth of 5580 m.

The question now is in how far the bottom content deviates at each station from the mean content determined at corresponding depths in the open sea? An answer is given in fig. 29 in which the full drawn line represents the mean oxygen depth curve. This curve was derived from the serial observations at stations 63, 64, 65, 66 and 67 [1]).

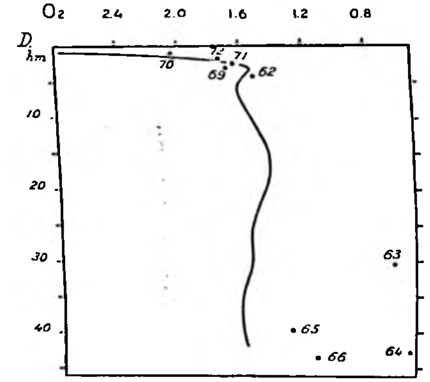


Fig. 29. Sulu sea. Comparison of the oxygen content near the bottom, obtained by means of wire-soundings, with the mean oxygen-depth curve, based on serial observations.

The observations near the sea floor are indicated by black dots; they show at stations 63, 64, 65 and 66 a marked deviation in relation to the full drawn line. The other stations correspond well with it. Of these stations 69 to 72 lie in the Sibutu strait and st. 62 is found to the north of the Basilan strait. It is comprehensible that at the last named stations the bottom content agreed with the mean serial values in the corresponding depths because of the excellent renewal of the water by strong currents in and near the Straits.

Although in arranging the programme of our activities I had reckoned upon a research over the *entire* Sulu sea, this proved to be impracticable. It is to be regretted that the original plan could not be carried out as a complete survey would have furnished information on the further course of the isolines and possibly shown a correspondence in the O_2-distribution in the bottom water with that of the Celebes sea. It is possible that in the Sulu sea, too, the bottom water moves along the NW-side in a south-westerly and southerly direction towards Sibutu strait by which the eastern part of the basin off the Basilan strait should be regarded as a dead point. The small O_2-content near the sea floor in this part of the basin might then be explained by a deficient transport near the bottom.

The bottom observations at stations 63 to 65 were carried out with the same reversing bottom water sampler; from the original notes it is not clear from which sampler the bottom water sample at st. 66 was taken.

Of the other inland seas the O_2-distribution in the bottom water of the Molukken sea shows some resemblance to that in the Timor trough. The water in these two areas is renewed by water from the Pacific and the Indian Ocean respectively. *The highest O_2-content is found near the axis of the two depressions*; from there it diminishes towards the margin.

A comparison of the bottom contents with the mean oxygen-depth curve shows in how far the floor affects the O_2-content of the bottom water, figs. 30 and 31.

Molukken sea. In fig. 30 the mean oxygen-depth curve was deduced from the serial observations of stations 80, 227, 284, 285, 288, 332 up to 336, 344, 345 and 347 [1]). These stations lie at the eastern and southern side of the middle ridge in the Molukken sea. The means for the depths of 3000 and 3500 m were determined from only two observations, viz. those from the two deep stations 284 (Morotai basin) and 80 (Batjan basin) which lie respectively in the extreme north and south of the area in question. The values used from these two stations differ about 0.30 cc/L in consequence of the conditions near st. 80 stated on p. 49, and in view of the gradual decrease of the O_2-content in the deep layers from the Pacific as they pass the successive thresholds.

[1]) p. 30.

The black dots indicate that the bottom water sample was taken with a serial water sampler. At the stations marked by a circle it was taken with a reversing bottom water sampler, and a correction of +0.1 cc/L has been applied when the observation depth is greater than 1500 m. Stations 81 and 82 are situated in the easterly arm of the Molukken sea to the north of the island of Obi Major. Fig. 30 shows that the O_2-contents of the northern stations lie the most to the left of the full drawn line, the southern to the right. This was to be expected in connection with the movement of the bottom water and the method of determining the course of the mean oxygen-depth curve. The deviations, in any case, indicate an only slight effect of the floor upon the O_2-content.

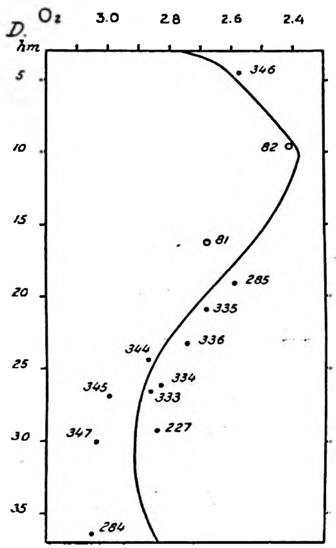


Fig. 30. Molukken sea. Comparison of the oxygen content near the bottom, obtained by means of wire soundings, with the mean oxygen-depth curve, based on serial observations.

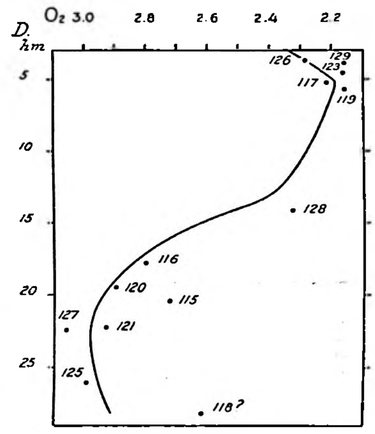


Fig. 31. Timor trough. Comparison of the oxygen content near the bottom, obtained by means of wire soundings, with the mean oxygen-depth curve, based on serial observations.

Timor sea. Fig. 31. The representation for the Timor sea given on Pl. I differs little from that for the Molukken sea. The means, with the help of which the full drawn line in fig. 31 is constructed were determined from the serial observations of stations 118, 120, 121, 125 and 127.

Of the bottom observations those at stations 115 and 118 deviate considerably from the mean oxygen-depth curve; st. 115 lies in the extreme north of the trough and there is some doubt as to the correctness of the bottom observation at st. 118, as has been said above [1]). It appears from the results of the remaining bottom observations that in the Timor sea, also, the O_2-content of the bottom water corresponds in the main to the bottom configuration. The water samples were taken with a reversing bottom water sampler, thus a correction of +0.1 cc/L was applied for depths exceeding 1500 m.

The oxygen distribution in the bottom water of the Sawoe sea and the Celebes sea as seen on Pl. I displays a different character to that in the two areas treated above.

Sawoe sea. Fig. 32. In the Sawoe basin near the botton *in the central area a minimum content was observed which increased towards the margin.* The connection between the bottom contents and the mean oxygen-depth curve is shown in fig. 32. This curve is deduced from the serial observations at the deep stations 153, 155, 159 and 163; the mean at 3200 m depth is based upon two observations only at stations 155 and 163, the results of which differ about 0.3 cc.

The bottom observations (black dots) were carried out with a reversing bottom water sampler,

[1]) p. 63.

with the exception of st. 381, where a serial sampler was used. The observations for a great part lie to the right of the curve which may be explained by an insufficient ventilation of the bottom water

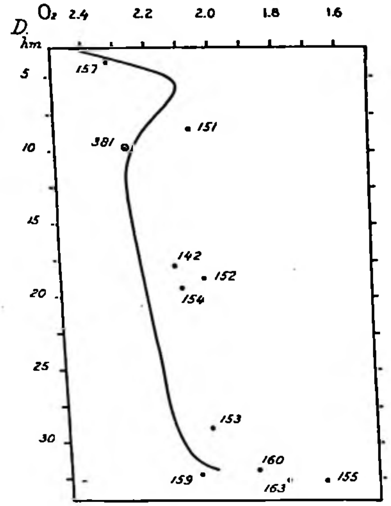


Fig. 32. Sawoe sea. Comparison of the oxygen content near the bottom, obtained by means of wire soundings, with the mean oxygen-depth curve, based on serial observations.

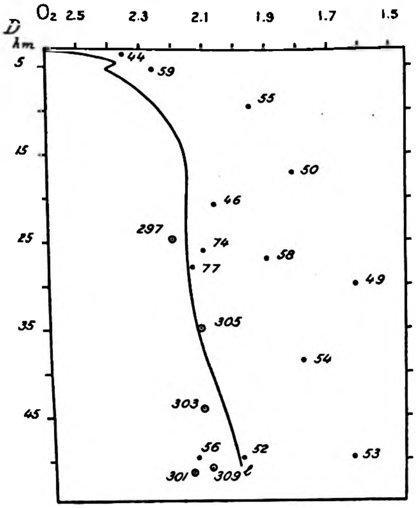


Fig. 33. Celebes sea. Comparison of the oxygen content near the bottom, obtained by means of wire soundings, with the mean oxygen-depth curve, based on serial observations.

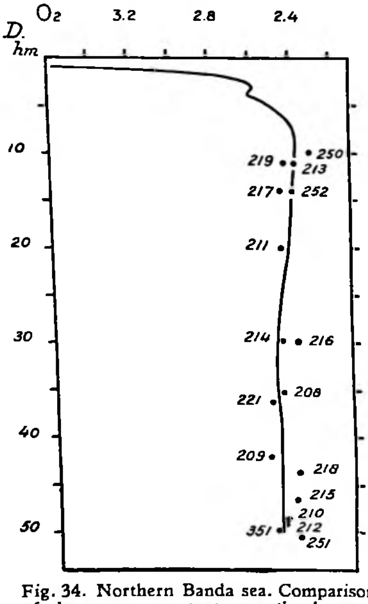


Fig. 34. Northern Banda sea. Comparison of the oxygen content near the bottom, obtained by means of wire soundings, with the mean oxygen-depth curve, based on serial observations.

through the narrow Ombai strait. In any case there is here no question of the bottom O_2-content following the bottom configuration.

Celebes sea. Fig. 33. Still less is this the case in the Celebes sea. But here the O_2-poor bottom water does not lie in the central part of the basin, but more to the south. As shown in fig. 33 the deviations of the bottom observations with regard to the mean oxygen-depth curve are much more marked than in the Sawoe sea. It is true that the entrance through which the bottom water flows (Ombai strait) is much narrower than that of the Celebes sea, but on the other hand, the latter basin has an area of 260000 km² within the depth-line of 4000 m, while the area of the Sawoe sea, limited by the 3000 m line, is 30000 km².

In fig. 33 the mean oxygen-depth curve is derived from the serial observations at sts. 47, 48, 52, 53, 56, 57, 75, 76 and 301 to 304. Of the bottom observations only those indicated by a dot with a circle were made with a serial water sampler. They lie in the area, as we suggested above [1]), through which the deep layers of Pacific water move and mostly seem to indicate an O_2-content which is higher than the mean in the open sea at the same level; the deviation, however, is not of importance. The majority of the remaining stations show a greater deviation in the opposite direction. Of these 49, 50, 53, 54 and 55 lie in the O_2-poor southern area of the basin; st. 58 lies in the extreme north.

[1]) p. 45.

Banda sea. Fig. 34. In sharp contrast to what we found above for the Sawoe and Celebes seas stand the results of the bottom observations in the Banda sea. The three areas, Northern Banda sea, Southern Banda sea and Weber deep are in connection with one another to a depth of fully 4000 m; together they form an area of 250000 km^2 within the depth line of 4000 m. In this basin, as in the Molukken and Timor seas, the O_2-content diminishes towards the borders.

We confine ourselves to the northern basin. The full drawn line again represents the mean oxygen-depth curve, deduced from the serial observations of the deep stations 209, 210, 212, 215, 218 and 331. The bottom oxygen contents deviate little from the mean curve; there is no evidence of a disturbing influence from the neighbourhood of the bottom. As we have remarked above the O_2-content at stations 215, 216 and 218 is probably affected by the bottom water transport from the gulf lying west of these stations. All bottom observations were made with a serial water sampler.

BOTTOM OXYGEN OBSERVATIONS

Explanation of Table 36.

1st Column. Station number. A cross refers to the notes printed below the table. In Vol. I we have given the position of the stations and the dates of observation. Some of the stations occurring in table 5 have been omitted in Table 36. In that case no wire soundings had been taken or no reliable bottom oxygen observations obtained when hauling up the bottom sample.

2nd Column. Bottom depth in metres.

3rd Column. Depth of observation in metres, determined as shown in Table 5. When the lowest serial observation was made at less than 50 m distance from the sea floor this observation was used in the absence of a bottom observation.

4th Column. Oxygen content in cc/L. Where there is a question mark it means there is some doubt of the accuracy of the observations; they are, however, not necessarily incorrect. When a correction of +0.1 cc/L is applied to the observed content the numbers are printed in bold type.

The multiple oxygen observations near the bottom have been dealt with above. Further particulars will be found in the notes printed below the table.

TABLE 36. Bottom Oxygen Observations.

St.	Depth	Depth of Obs.	O_2	St.	Depth	Depth of Obs.	O_2	St.	Depth	Depth of Obs.	O_2
25	61	56	2.64	50	1713	1682	**1.81**	73	1299	1268	2.07
26	81	76	4.07	51	388	357	3.04	74	2637	2606	**2.10**
27	61	56	3.76	52	5017	4986	**1.98**	75	4773	4742	**2.10**
28	70	65	2.97	53	5004	4973	**1.62**	76*	5544	5483?	0.78?
29	683	652	1.96	54	3917	3886	**1.78**	77	2791	2760	**2.14**
30	1771	1740	**1.67**	55	983	952	1.95	78	1499	1468	2.23
32	622	591	2.18	56	5009	4978	**2.12**	79	2614	2583	**2.60**
33	1932	1901	**1.88**	58	2722	2691	**1.90**	80*	4617	4586	2.63
35	2003	1972	**1.89**	59	544	513	2.26	81	1666	1635	**2.68**
36	1116	1085	1.86	60	90	85	4.05	82	989	958	2.39
37	56	51	3.58	62	452	421	1.51	83	378	347	2.69
38	1371	1340	1.98	63	3067	3036	**0.65**	84	1527	1496	2.38
39*a*	2164	2133	2.13	64	4299	4268	**0.57**	85	679	648	2.53
40	1144	1113	1.90	65	3981	3950	**1.30**	86	386	355	2.75
41	2373	2342	**2.10**	66*	4483	4452	1.14	87	436	405	2.15
42	690	659	1.93	69	334	303	1.69	88	558	527	2.28
44	400	369	2.36	70*	125	100	2.14	89	1415	1384	2.35
46	2088	2057	2.07	71	263	232	1.64	91	247	216	2.59
49	3010	2979	**1.61**	72	198	167	1.73	92	682	651	2.11

St.	Depth	Depth of Obs.	O_2	St.	Depth	Depth of Obs.	O_2	St.	Depth	Depth of Obs.	O_2
93	1064	1033	2.07	146	5371	5340	4.32	200	1098	1065	2.27
94	755	724	2.09	147	3675	3644	3.85	201	2969	2936	2.45
95	1825	1794	2.32	148	1201	1170	2.24	202*	3898	3835	2.39
96	854	823	2.18	149	1363	1332	1.88	203	3500	3467	2.43
97*	2326	2295	2.34?	150	203	172	3.24	204	1483	1450	2.36
98	564	533	2.23	151	896	865	2.07	205*	3936	3873	2.45
100*	3594	3563	1.67?	152	1918	1887	2.04	207	1186	1153	2.32
101	2139	2108	2.27	153	2928	2897	2.04	208	3556	3523	2.46
102	372	341	1.83	154	1976	1945	2.11	209*	4225	4202	2.53
103	671	640	2.03	155	3298	3267	1.67	210	4907	4874	2.45
104*	3296	3205	2.25	156	1856	1825	2.99	211	2025	1992	2.45
105	924	893	2.06	157	438	407	2.32	212*	4968	4958?	2.46
106	714	683	1.67	159	3250	3219	2.08	213	1135	1102	2.38
107	385	354	2.09	160	3221	3190	1.89	214	3002	2969	2.45
108	573	542	1.70	161	979	948	2.13	215	4697	4664	2.40
109*	1504	1473	2.49	162*	2008	1977	2.01?	216	3017	2984	2.38
110*	233	202	2.28	163*	3296	3235	1.80	217	1422	1389	2.45
111	557	526	2.02	164	3834	3803	2.43	218	4404	4371	2.39
112	1528	1497	2.51	165	435	404	2.28	219	1129	1096	2.42
113	627	596	2.21	166	2002	1971	2.24	221	3649	3616	2.51
114	1437	1406	2.28	167	3448	3417	2.29	223	486	453	2.71
115	2070	2039	2.72	168*	2559	2528	1.69?	224	1085	1052	2.48
116	1809	1778	2.80	169	576	545	2.28	225	1911	1878	2.49
117	553	522	2.22	172	714	693	1.94	226	426	393	2.61
118*	2843	2812	2.62?	173	1511	1478	2.06	227	2967	2934	2.85
119	604	573	2.16	174	1216	1183	2.06	228	2590	2557	2.57
120	1981	1950	2.90	176	637	604	2.15	229	5133	5100	2.56
121	2254	2223	2.93	178	2726	2693	2.30	230	1402	1369	2.39
123	490	459	2.17	179	3947	3914	2.25	231	1094	1061	2.36
125	2609	2578	2.99	180*	5033	4970	2.04	232	4596	4563	2.52
126	409	378	2.29			5000	2.16	233	1761	1728	2.55
127	2285	2254	3.06	181	2832	2799	2.35	236	3597	3564	2.40
128	1440	1409	2.33	182	890	857	2.08	237	3168	3135	2.37
129	425	394	2.16	183	503	470	2.18	239	1236	1203	2.34
130	1826	1795	3.22	184	357	324	2.42	240	3130	3097	2.43
131	2901	2870	3.65	185	620	587	2.17	241	4829	4796	2.46
132	1303	1272	2.27	186	1401	1368	2.35	242	3341	3308	2.43
133	493	462	2.01	187	3098	3065	2.21	244	2565	2532	2.40
134	939	908	1.89	188	1023	990	2.09	245*	4423	4390	2.30?
135	1155	1124	2.20	189	1862	1829	2.32	246*	4364	4331	2.40?
136	367	336	2.31	190	1407	1374	2.22	247	1519	1486	2.34
137	440	409	2.13	191	1991	1958	2.34	248	2645	2612	2.46
138	946	915	2.06	192	2552	2519	2.38	249	4091	4058	2.45
139	407	376	2.22	193	1689	1656	2.37	250	1027	994	2.30
140	1071	1040	2.25	194	2691	2658	2.33	251	5078	5045	2.39
142	1821	1790	2.13	195	504	471	2.24	252	1414	1381	2.39
143	1641	1610	2.70	196	2216	2183	2.31	253*	4024	3991	2.42
144	2769	2738	3.52	197	5133	5100	2.28	255	3218	3185	2.50
145*	5722	5661?	3.97?	198	2804	2771	2.26	256	1197	1164	2.44

St.	Depth	Depth of Obs.	O_2	St.	Depth	Depth of Obs.	O_2	St.	Depth	Depth of Obs.	O_2
260	7830	7797	3.47	298	806	773	2.33	347*	3061	3011	3.04
261*l*	9877	9844	3.48	300	665	632	2.50	350	2558	2525	2.99
265	4886	4853	3.46	301	5171	5138	2.14	351	788	755	2.58
266	2382	2349	2.84	303	4419	4386	2.10	352	1018	985	2.92
268	782	749	2.36	305	3507	3474	2.11	353	1872	1839	2.92
269	567	534	2.59	309*l**	5108	5075	2.08	354	579	546	2.77
270	4711	4678	3.45	320	2564	2531	2.37	354*a*	1365	1332	2.51
275	5515	5482	3.49	321	6625	6592	2.40	355	2049	2016	2.55
276	4299	4266	3.42	322	3314	3281	2.40	357	1579	1546	2.40
277	567	534	2.83	323	496	463	2.26	358	4467	4417	2.38
278*	474	441	0.00	324	2139	2106	2.36	359	3549	3516	2.45
	491	461	0.00	325	1996	1963	2.54	360	1093	1060	2.33
280*	369	336	0.14	326	474	441	2.61	361	2629	2596	2.43
	357	297	0.24	327	1445	1412	2.52	362*	7326	7293	2.38
284	3684	3651	3.06	328	2942	2909	2.53	363	898	865	2.32
285	1949	1916	2.60	330*	4450	4420	2.55	364	1071	1038	2.27
286	624	591	2.64	331*	5026	4976	2.50	364*a*	4435	4395	2.40
287	668	635	2.53	333	2694	2661	2.87	365	6313	6280	2.39
288	2201	2168	3.02	334	2658	2625	2.83	368	2451	2418	2.39
289	1569	1536	2.26	335	2130	2097	2.69	369	4468	4435	2.37
291	2517	2484	2.64	336	2378	2345	2.75	370	1685	1652	2.36
292	2443	2410	2.65	339	398	365	2.53	372	940	907	2.29
293	847	814	2.24	340	2510	2477	2.73	374*	2509	2459	2.40
294	1825	1792	2.59	341*	1305	1285	2.37	375	1422	1389	2.34
295	920	887	2.19	344	2479	2446	2.87	376	3292	3259	2.39
296	3322	3289	2.73	345	2736	2703	3.00	377	3347	3314	2.37
297	2541	2508	2.20	346	492	459	2.58	381	1016	983	2.27

NOTES TO TABLE 36.

St. 66. See multiple bottom observations. p. 36. *St. 70*. Bottom observation at 100 m. *St. 76*. Possibly the bottom water samplers were dragged along the sea floor. See multiple bottom observations. *St. 80*. As st. 66. *St. 97*. The uncorrected value of 2.24 agrees better with the serial observations. *St. 100*. The bottom observations are not trustworthy. *St. 104*. As st. 66. *St. 109*. Temp. and salinity show some deviation near the bottom; possibly O_2 is also inaccurate. A further examination of temperature and salinity will show whether the effect of water transport from the Indian Ocean is felt here and at other stations. *St. 110*. The lowest serial observation gave 2.34 cc at 200 m depth. *St. 118*. The bottom observations are not quite reliable. *St. 145*. As st. 66. *St. 162*. Bottom O_2-content doubtful. *St. 163*. As st. 66. *St. 168*. The sudden change in the O_2-content near the bottom is here rather suspicious. *St. 180*. As st. 66. The content of 2.04 was determined from a water sample taken with an antiquated Sigsbee sampler. 5000 m — lowest serial observation. *Sts. 202, 205, 209 and 212* as st. 66. *Sts. 245 and 246*. The observations were carried out with an antiquated Sigsbee water sampler. At st. 246 muddy water in sampler. *St. 253*. As st. 66. *Sts. 278 and 280*. As st. 66. Two wire soundings. *Sts. 309 l, 330, 331, 341, 347, 362 and 374* as st. 66.

LITERATURE

1. Forschungsreise S.M.S. „Gazelle", 1874—1876. Physik und Chemie, 1888.
2. Forschungsreise S.M.S. „Planet", Band III. Ozeanographie, 1906—1907.
3. Reports of the scientific results of the voyage of H.M.S. „Challenger". Physics and Chemistry, Vol. I, 1873—1876.
4. HELLAND-HANSEN, BJ., Physical Oceanography and Meteorology, Vol. I, 1910. Results of the „Michael Sars" North Atlantic deep-sea Expedition, 1930.
5. SCHOTT, G., Adiabatische Temperaturänderung in groszen Meerestiefen. Ann. der Hydr. u. M. Meteor. 1914.
6. WÜST, G., Bodentemperatur und Bodenstrom in der Pazifischen Tiefsee. Veröff. d. Inst. f. Meereskunde. N.F.A., Heft 35, 1937.
7. TAIT, P. G., The pressure errors of the „Challenger" thermometer. „Challenger" Reports. Narrative Vol. II. London, 1882.
8. WYVILLE THOMSON, SIR C., The voyage of the „Challenger". The Atlantic, Vol. II, p. 304. London 1877.
9. MÖLLER, L., Methodisches zu den Vertikalschnitten im Atlantischen. Veröff. d. Inst. f. Meereskunde. N.F.A., Heft 15, 1926.
10. WÜST, G., Schichtung und Tiefenzirkulation des Pazifischen Ozeans. Veröff. d. Inst. f. Meereskunde. N.F.A., Heft 20, 1929, p. 14.
11. HAMAKER, H. C., Methods and Instruments, Snellius-expedition. Vol. II Part I Ch. I, 1941.
12. PINKE, F., Depth determinations. Snellius-expedition. Vol. II Part 2 Ch. I, 1935.
13. LEK, L., Die Ergebnisse der Strom- und Serienmessungen. Snellius-expedition. Vol. II Part 3, 1938.
14. HARDON, H. J., Methods and Instruments. Snellius-expedition. Vol. II Part 1 Ch. II.
15. KNUDSEN, M., Publ. de Circonstance, 77, 1923.
16. WATTENBERG, H., Die Verteilung des Sauerstoffs im Atlantischen Ozean. Wiss. Erg. der Deutschen Atl. Exp. auf dem „Meteor", 1925—1927. Band IX, 1. Teil, 1. Lieferung, Berlin, 1938.
17. WATTENBERG, H., Kalziumkarbonat- und Kohlensäuregehalt des Meerwassers. Wiss. Erg. der Deutschen Atl. Exp. auf dem „Meteor", 1925—1927. Band VIII, 1. Teil, Berlin, 1933.
18. KUENEN, PH. H., Die Viermeter-Lotröhre der Snellius-Expedition. Ann. d. Hydr. u. M. Meteor. 1932, p. 93.
19. STROM, K. M., Land-locked waters, Oslo. I kommisjon hos Jacob Dybwad, 1936, p. 75.
20. RINGER, W. E., Temperatuur, zoutgehalte, dichtheid en gasgehalte van het zeewater. De Zeeën van Nederlandsch Oost-Indië. E. J. Brill, Leiden, 1922.
21. WÜST, G., Das Bodenwasser und die Gliederung der Atlantischen Tiefsee. Wiss. Erg. der Deutschen Atl. Exp., Meteor, 1925—1927. Berlin, 1933.

LIST OF PUBLICATIONS CONCERNING THE SNELLIUS-EXPEDITION (Until 1943)

SNELLIUS-REPORTS

GENERAL

P. M. van Riel, Program of Research and Preparations. The Snellius-expedition. Vol. I, Chapter I, 1937. *E. J. Brill, Leiden.*

F. Pinke, The Expeditionary Ship and the Naval Personnel's Share. The Snellius-expedition, Vol. I, Chapter II, 1938, *E. J. Brill, Leiden.*

J. P. H. Perks, The Deep-sea Anchorage Equipment .The Snellius-expedition, Vol. I, Chapter II, Appendix, 1938. *E. J. Brill, Leiden.*

P. M. van Riel, The voyage in the Netherlands East-Indies. The Snellius-expedition, Vol. I, Chapter III, 1938. *E. J. Brill, Leiden.*

H. Boschma and Ph. H. Kuenen. Investigations on shore. The Snellius-expedition, Vol, I, Chapter IV, 1938. *E. J. Brill, Leiden.*

OCEANOGRAPHY

H. C. Hamaker. Methods and Instruments. The oceanographic instruments and the accuracy of the temperature observations. The Snellius-expedition, Vol. II, Part 1, *Chapter I,* 1941. *E. J. Brill, Leiden.*

H. J. Hardon. Methods and Instruments. The determination of chlorine and oxygen content. The Snellius-expedition, Vol. II, Part 1, *Chapter II,* 1941. *E. J. Brill, Leiden.*

F. Pinke. Depth Determinations. The Snellius-expedition, Vol. II, Part 2, *Chapter I,* 1935. *E. J. Brill, Leiden.*

P. M. van Riel. The bottom configuration in relation to the flow of the bottom water. The Snellius-expedition, Vol. II, Part 2, *Chapter II,* 1934. *E. J. Brill, Leiden.*

L. Lek, Die Ergebnisse der Strom- und Serienmessungen. The Snellius-expedition, Vol. II, Part 3, 1938. *E. J. Brill, Leiden.*

S. W. Visser. Surface-observations, Temperature, Salinity, Density. The Snellius-expedition, Vol. II, Part 4, 1938. *E. J. Brill, Leiden.*

P. M. van Riel. The bottom water. Introductory Remarks and Oxygen Content. The Snellius-expedition, Vol. II, Part 5, *Chapter I,* 1943. *E. J. Brill, Leiden.*

METEOROLOGY

S. W. Visser. Meteorological Observations. The Snellius-expedition, Vol. III, 1936. *E. J. Brill, Leiden.*

GEOLOGY

Ph. H. Kuenen. Geological interpretation of the bathymetrical results. The Snellius-expedition, Vol. V, Part 1, 1935. *E. J. Brill, Leiden.*

Ph. H. Kuenen. Geology of Coral Reefs. The Snellius-expedition, Vol. V, Part 2, 1933. *E. J. Brill, Leiden.*

BIOLOGY

H. Boschma. Biological data. The Snellius-expedition, Vol. VI, 1935. *E. J. Brill, Leiden.*

BIOLOGICAL RESULTS OF THE SNELLIUS-EXPEDITION. Published in „Temminckia"

Austin H. Clark. I. The unstalked crinoids of the Snellius-expedition. Temminckia, Vol. I, 1936. *E. J. Brill, Leiden.*

I. van Baal. II. Rhizocephala of the families Peltrogastridae and Lernaeodiscidae. Temminckia, Vol. II, 1937. *E. J. Brill, Leiden.*

G. Stiasny. III. Die Fundorte der Scyphomedusen und Tornarien. Temminckia, Vol. II, 1937. *E. J. Brill, Leiden.*

A l i d a M. B u i t e n d ij k. IV. The Paguridea of the Snellius-expedition. Temminckia, Vol. II, 1937. *E. J. Brill, Leiden.*

A l i d a M. B u i t e n d ij k. V. The Dromiacea, Oxystomata, and Oxyrhyncha of the Snellius-expedition. Temminckia, Vol. IV, 1939. *E. J. Brill, Leiden.*

J e n t i n a E. L e e n e. VI. The Portunidae of the Snellius-expedition. Temminckia, Vol. V, 1940. *E. J. Brill, Leiden.*

G. S t i a s n y. VII. Die Gorgonarien-Sammlung der Snellius-Expedition. Temminckia, Vol. V, 1940. *E. J. Brill, Leiden.*

H. B o s c h m a. VIII. Some Rhizocephala of the Genus Loxothylacus. Temminckia, Vol. V, 1940. *E. J. Brill, Leiden.*

H. S h i l p. IX. The Chaetognatha of the Snellius-expedition. Temminckia, Vol. VI, 1941. *E. J. Brill, Leiden.*

G. C. A. J u n g e. X. Aves. Temminckia, Vol. VI, 1941. *E. J. Brill, Leiden.*

W. V e r v o o r t. XI. The Hydroida of the Snellius-expedition (Milleporidae and Stylasteridae excluded). Temminckia, Vol. VI, 1941. *E. J. Brill, Leiden.*

L. B. H o l t h u i s. XII. The Stomatopoda of the Snellius-expedition. Temminckia, Vol. VI, 1941. *E. J. Brill. Leiden.*

A. M. B u i t e n d ij k. XIII. On some Xanthidae, chiefly of the genus platypodia bell. Temminckia, Vol. VI, 1941. *E. J. Brill, Leiden.*

REMAINING PAPERS AND COMMUNICATIONS

P. M. v a n R i e l. Een Nederlandsche Oceanografische Expeditie in den Oost-Indischen Archipel; de Zee, 1928, *p.* 292, 347.

P. M. v a n R i e l. Die geplante Niederländische Expedition in die Meere des Ostindischen Archipels. Ergänzungsheft III der Zeitschrift der Gesellschaft für Erdkunde zu Berlin, 1928, *S.* 34.

J. L u y m e s. Korte schets van de ontwikkeling der Oceanografie en de expeditie van H. M. „Willebrord Snellius". Tijdschrift van het Kon. Ned. Aardrijksk. Genootschap. 1929, *p.* 337.

P. M. v a n R i e l. The Netherlands Oceanographic Expedition in the East Indian Archipelago. Proceedings Fourth Pacific Science Congress, Java. 1929, *p.* 541.

J. L u y m e s. Short Sketch of the Progress of Oceanography and of the Expedition of the Royal Dutch vessel „Willebrord Snellius". Hydrographic Review 1930,*p.* 142.

P. M. v a n R i e l. The Snellius-expedition. Nature, May 17, 1930.

E. v a n E v e r d i n g e n. The Snellius-expedition. Journal du Conseil international pour l'exploration de la mer. Vol. 5, *No.* 3, 1930, *p.* 320.

Snellius-expeditie. Verslagen. (Reports of progress). Tijdschrift van het Kon. Ned. Aardrijksk. Genootschap, 1929, *p.* 530, 721; 1930, *p.* 29, 380, 708, 801, 991; 1931, *p.* 181.

Snellius-expeditie. Verslagen. (Reports of progress by the Indian Committee for Physical Researches). 1930, *Eerste en tweede;* 1931, *derde Bulletin van de Willebrord-Snellius-expeditie.*

P. M. v a n R i e l. Ozeanographische Forschung in Niederländisch-Ostindien. Zeitschrift der Gesellschaft für Erdkunde zu Berlin, 1932, *p.* 208.

Ph. H. K u e n e n. Die Viermeter-Lotröhre der Snellius-Expedition. Ann. d. Hydrogr. u. Mar. Meteor. 1932, *p.* 93.

P. M. v a n R i e l. Einige ozeanographische Beobachtungen im Roten Meer, Golf von Aden und Indischen Ozean. Ann. d. Hydrogr. u. Mar. Meteor. 1932, *p.* 401.

P. M. v a n R i e l. The Snellius-expedition, Journal du Conseil pour l'exploration de la mer. Vol. 7 *No.* 2, 1932, *p.* 212.

P. D. T r a s k. Origin and Environment of Source Sediments of Petroleum. American Petroleum Institute, 1932, *p.* 146—147.

H. C. H a m a k e r. Results obtained with a Thermograph for Surface Temperatures during the Snellius-expedition, Journal du Conseil pour l'exploration de la mer. Vol. 8, *No.* 1, *p.* 64.

Ph. H. K u e n e n. The formation of the atolls in the Toekang Besigroup by subsidence. Verh. Kon. Akad. v. Wet., Amsterdam, 1933, *p.* 331.

G. S t i a s n y. Die Tornarien der Snelllius-Expedition. Verh. Kon. Akad. v. Wet., Amsterdam. Dl. 38, *No.* 9, 1935.

G. S t i a s n y. Die Scyphomedusen der Snellius-Expedition. Verh. Kon. Akad. v. Wet., Amsterdam. Dl. 34, *No.* 6, 1935.

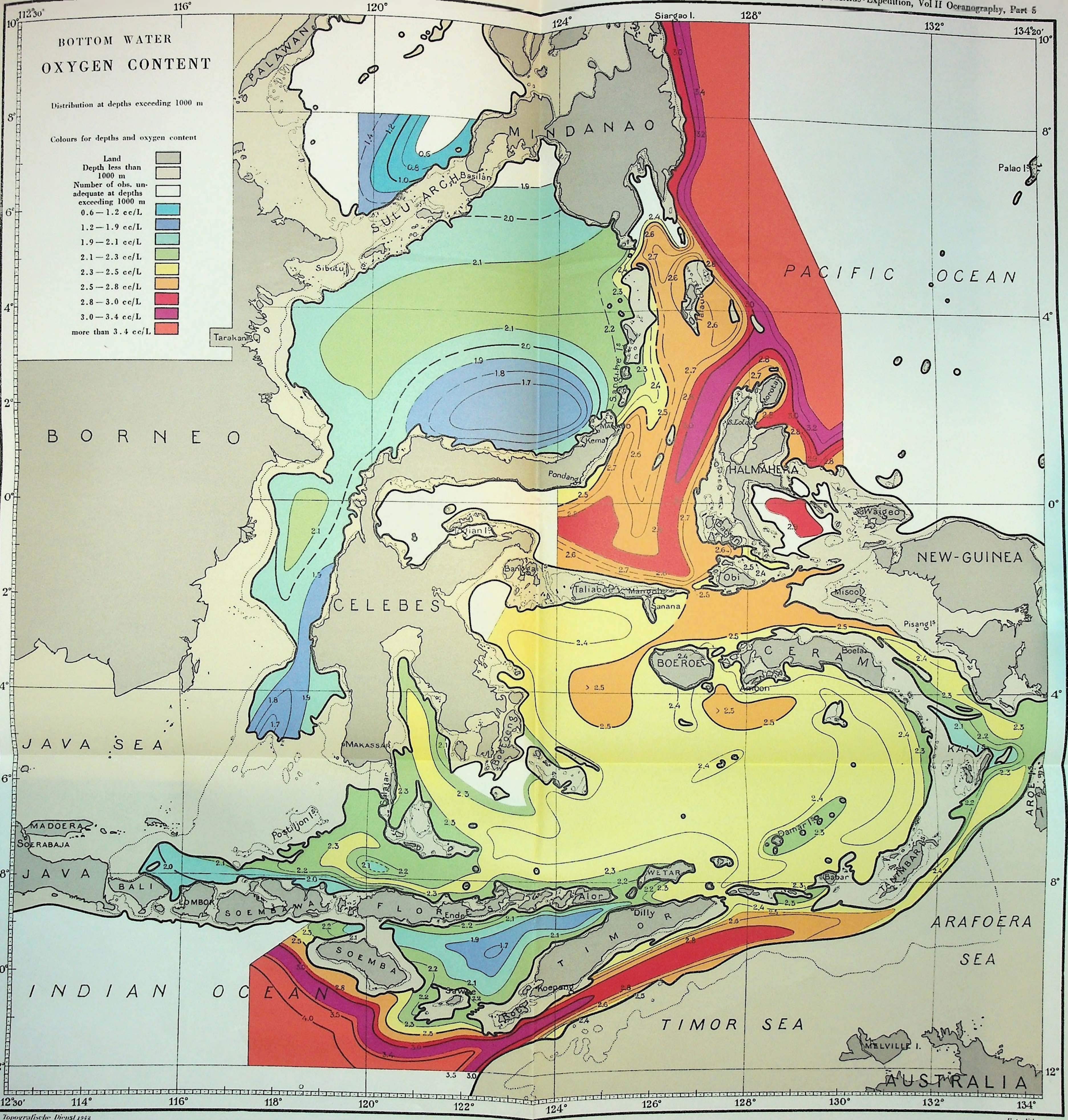
Ph. H. Ku e n e n. Submarine slopes of volcanoes and coral reefs in the East Indian Archipelago. Comp. Rend. Congr. Intern. de Géographie. Amsterdam 1938, *T. II, Sex. IIb, Océanographie, p.* 93—98.

J. H. F. U m b g r o v e. Corals from an elevated marl of Talaud (*East-Indies*). *Zoöl. Med., Dl. XX, p.* 263—274, 1938.

J. H. F. U m b g r o v e. Miocene corals from Flores (*East-Indies*). *Leidsche Geol. Med., Dl. XI, p.* 62—67, 1939.

Ph. H. K u e n e n. Contributions to the Geology of the East-Indies from the Snellius-expedition. Part I, Volcanoes. Leidsche Geol. Med., Dl. VII, p. 273—331, 1939.

Ph. H. K u e n e n. Kruistochten over de Indische diepzeebekkens. Leopold's Uitg. Mij. 's-Gravenhage, 1941.



Topografische Dienst 1942

Scale 1:6,500,000